# STUDIES ON OPTIMIZATION OF AGRO-TECHNIQUES TO MAXIMIZE PRODUCTIVITY OF WINTER MAIZE (*Zea mays* L.) AND EVALUATION OF DSSAT v 3.5 CERES MAIZE MODEL

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# I. INTRODUCTION

Maize (*Zea mays* L.) is emerging as an important cereal crop in the world after wheat and rice, and is now an important ingredient in food, feed and large number of industrial products. It has acquired dominant role in the farming sector and macro-economy of the Asian region (Mauria *et al*., 1998). It has the highest potential of per day carbohydrate productivity. Thus, it is not without any basis the father of green revolution, the renowned Noble Laureate, Dr. Norman E. Borlaug, believes that "After the last two decades saw the revolution in rice and wheat, the next few decades will be known as maize era" (Patil *et al*., 2000).

In India, maize is grown on an area of 6.6 million ha with the grain production of 12.1 million tonnes, with an average productivity of 1.83 $ha^{-1}$ (Anon, 2003a), which is nearly five fold increase since the fifties. Though, maize in India can be grown in all the three seasons namely *kharif, rabi* and summer, cultivation during winter season is spreading in entire plain region of the country where temperature during the growth periods does not go below $10^0$ C (Anon, 1997).

The winter maize with its high productivity potential has opened up a viable alternative. Cultivation during winter is becoming a common practice in peninsular India (Andhra Pradesh, Karnataka and Tamil Nadu), as well as in the north-eastern plains. Because of its potential to yield as high as 10 to12 t $ha^{-1}$, and further increase in productivity substantially upto 18 t $ha^{-1}$ with better management, the winter maize cultivation is increasing not only in Bihar but also in other states (Singh, 1998). Presently, winter maize is being grown in an area of about 0.58 million ha with an average productivity of 12 t $ha^{-1}$ under experimental conditions and 6 to 8 t $ha^{-1}$ under farmers conditions (Anon, 2000).

In Karnataka, maize is grown on an area of 6.9 lakh ha with a production of 21.4 lakh tonnes with an average productivity of 3.4 t $ha^{-1}$ (Anon, 2003b). The important maize growing districts are Belgaum, Dharwad, Chitradurga, Bijapur, Bellary, Mysore and Shimoga. During winter season, maize in Karnataka occupies around 46,400 ha contributing nearly 1,09,700 tonnes with a productivity level of 2489 kg $ha^{-1}$. Nearly 99 per cent of winter maize area is under irrigated condition as against 47 per cent during *kharif* season. Winter maize in most of the irrigated commands is increasing, specially in Malaprabha, Ghataprabha, Tungabhadra and Upper Krishna Irrigation Projects of North Karnataka. In these commands, nearly eighty per cent of the area is covered with black soil (vertisol) and *rabi* sorghum area is substituted by winter maize, because of its higher productivity.

The productivity level of winter maize should be higher as compared to *kharif* sown maize because of comparatively favourable environmental conditions in peninsular India as compared to North India (Mauria *et al*., 1998). However, within the peninsular India, the productivity of winter maize is much lower in Karnataka in general and Northern Karnataka in particular. The lower yield in Karnataka could be attributed to non availability of suitable genotypes, delay in sowing due to non-availability of land, sub optimum supply of water and nutrient, specially the nitrogen and lower plant density as evidenced in other parts of our country (Singh, 1998). Therefore, concerted efforts are needed to develop suitable agro-techniques to enhance the productivity of winter maize.

The productivity potential of hybrid/composite cannot be realized without proper management practices. The optimum date of sowing is important for winter maize so that the genotype grown can complete its life cycle under optimum environmental conditions. Optimum plant density provides conditions for maximum light interception right from early periods of crop growth. Although, winter maize responds better even upto 90,000 to 1,00,000 plants $ha^{-1}$ (Singh *et al*., 1997; Singh and Zaidi, 1998), the recommended plant population during winter in Northern Karnataka is only 55556 plants $ha^{-1}$ as that of monsoon crop. Moreover, only few studies have been conducted to evaluate the response of *rabi* maize to plant density under irrigated conditions.

Maize production is limited by nitrogen deficiency more often than that of any other nutrients. In view of more favourable growing condition during *rabi* season, the response to the application of nitrogen is comparatively better as compared to rainy season (Singh and Zaidi, 1998). Although considerable work has been done in India on nitrogen requirement of maize, but meager attempt has been made on nitrogen requirement of winter maize grown under this environment.

Water is crucial input for augmenting agricultural production towards sustainability in agriculture. Scientific water management aims to provide suitable soil-moisture environment to the crop to obtain optimum yield commensurate with maximum economy in irrigation water and maintenance of soil productivity. There has been a perceptible change in the cropping pattern in irrigated commands of Northern Karnataka. As a result, the demand for irrigation water has become more exacting now than ever before, and the need for more efficient water management on the field is being strongly felt.

During the winter season less water is required at early stage of crop while, at later crop growth stages water requirement increases due to rapid increase in evapo-transpiration demand. Amongst the various irrigation scheduling approaches, climatological approach has been found to be better, since it integrates all the weather parameters giving them their natural weightage in a given climate-water-plant continuum (Prihar and Sandhu, 1987). A more practicable and understandable approach based on the ratio of fixed amount of irrigation water (IW) to cumulative pan evaporation (CPE) is much desired. Moreover, a close relationship exists between the rate of consumptive use of crop and the rate of evaporation. Northern Karnataka, very scanty work has been done on irrigation water requirement of winter maize based on IW:CPE ratio in relation to nitrogen dose and plant density.

In agriculture, prediction of crop yield could be of immense use to the planners (Kaur and Hundal, 1998) to take policy decisions on advanced planning of internal food distribution, relief measures, grain storage, fixing of levy prices and even providing alternative employment in drought affected areas. Regression models are widely used to predict yields (Gangopadhyaya and Sarkar, 1964; Huda *et al.*, 1975; Huda *et al.*, 1985). The national and/ or state research centers which have mandates to cover large areas can neither afford nor do they have time to develop empirical models which are location specific for each combination of soil, climate, variety and management practices.

The process-based dynamic simulation crop models based on soil, crop and weather factors could be effective research tools for planning alternative strategies for crop management, land use and water management (Jordan, 1983; Whisler *et al.*, 1986; Engel *et al.*, 1997; Matthews *et al.*, 2002) and also a useful tool for planning and developing technological interventions in diverse areas like India (Aggarwal and Kalra, 1994; Singh *et al.*, 1994a; Singh *et al.*, 1994b; Lal *et al.*, 1999). For research planning a validated model with known genetic constants for varieties can be a powerful tool for studying the performance of varieties in constrating environments, soil types, diverse cultural practices and management inputs (Boote *et al.*, 1996). Technological packages including optimum planting time, timing and amount of fertilizer, irrigation, plant population and planting geometry can be designed using models (Jagtap *et al.*, 1993). Though this approach has been successfully used in some parts of our country for management decisions and technology evaluation, no efforts have been made in this region. The DSSAT v 3.5 CERES maize crop simulation model which was tested over a wide range of environments (Tsuji *et al.*, 1994; Hoogenboom *et al.*, 1999) has been used in the present investigation.

The review of literature reveals that development of agronomic packages that improve and stabilize production of winter maize in Northern Karnataka needs special attention. The important components are suitable genotypes, appropriate planting date(s), optimum nitrogen dose and plant density coupled with judicious and timely supply of required amount of water. In addition, evaluating the potential role of a crop simulation model use in agronomic investigations, which takes into account the considerable environmental variations that occur within the region is very much needed to minimize the time and money required in developing agronomic packages. In view of the facts elaborated, the present investigation entitled "Studies on optimization of agro-techniques to maximize productivity of winter maize (*Zea mays* L.) and evaluation of DSSAT v 3.5 CERES – Maize Model" was undertaken with the following objectives.

1. To know the performance of maize varieties to different planting dates during winter season.

2. To study the effect of irrigation scheduling, plant density and nitrogen levels and maximize the yield of winter maize.

3. To generate the genetic coefficients of maize varieties for running DSSAT v 3.5 CERES maize model

4. To evaluate the DSSAT v 3.5 CERES maize model for simulating the growth and yield of maize varieties as influenced by planting dates and compare with the field data.

5. To examine the performance of DSSAT v 3.5 CERES maize model for simulating the effect of irrigation scheduling, plant density and nitrogen levels on growth and yield of maize and compare with the measured data.

# II. REVIEW OF LITERATURE

An attempt made to review the literature pertinent to the objectives of the present investigation are presented under different headings in this chapter.

## 2.1 VARIETAL RESPONSE

Maize varietal performances vary considerably from one production environment to the other (Muleba *et al*, 1983a). In each production environment, the characteristics associated with high yield varies (Muleba *et al*., 1983b) with genotypes.

The total yield of maize was associated with leaf area, its display and carbondioxide supply (Loomis and Williams, 1963). The higher leaf area of double cross hybrid (P-309B) as compared to single cross hybrid (D-XL65) at silking stage was reflected in higher yield of maize at equivalent population (Brown *et al.,* 1970).

The grain yield depends on the LAI and efficiency of the photosynthetic system and duration of the active photosynthesis (Watson, 1963). The LAI and other growth components differed significantly with different genotypes (Krishnamurthy *et al*., 1973b; Setty, 1981; Muleba *et al*. 1983 a and 1983b; Manishkumar, 1998).

The maximum grain yield of maize obtained at LAI of 3.3 at silking (Eik and Hanway, 1966) and maximum LAI of 3.5 and beyond, no net increase in grain yield (Nunez and Kamprath, 1969). The LAI increased gradually from seedling stage (0.02) to silking stage (2.5) and declined afterwards probably due to the senescence of lower leaves (Krishnamurthy *et al*., 1973b). At Dharwad, during *rabi* season in vertisols under irrigated conditions more or less similar trend in average LAI was registered. An average LAI of 0.85 recorded at 30 days was the lowest, and reached the maximum of 60 days (4.56) and gradually decreased upto 90 days (3.35) and then decreased (1.23) rapidly towards physiological maturity (Setty, 1981).

The higher mean LAI of 1.81 in Mexican June and lower LAI of 0.44 in Arabhavi local was associated with higher and lower yields respectively. Similarly, Mexican June recorded higher mean leaf area duration (26.6 weeks) and crop growth rate (1.2 g $dm^{-2}$ $week^{-1}$) and Arabhavi local recorded minimum mean LAD (5.7 weeks) and CGR (0.33 g $dm^{-2}$ $week^{-1}$). All the genotypes which registered higher mean LAI (upto 1.5), LAD (upto 20 weeks) and CGR (upto 0.9 g $dm^{-2}$ $week^{-1}$) produced more grain yield $ha^{-1}$ as compared to Arabhavi-local in which these growth components and grain yield were low (Krishnamurthy *et al*., 1973b). During *rabi* season at Dharwad, among different genotypes, EH-400175 showed LAI on par with Deccan at 30, 60 and 90 days, but higher than Deccan at physiological maturity, while G-2 composite and Arabhavi local recorded significantly lower LAI. Thus, higher LAI manifested higher yield in EH-400175 and Deccan than G-2 composite and Arabhavi local, (Setty, 1981). Similarly, during winter season Manishkumar (1998) noticed higher yield of RH-1 and PA hybrids than Devika composite. This was attributed to higher LAI of RH-1 and PA hybrids than Devika which registered lower LAI.

In addition, the difference in LAI was noticed with difference in maturity group. The late maturity group hybrids recorded maximum LAI as compared to early maturity hybrids (Alessi and Power, 1975). And, with this it was concluded that the yield differences among genotypes were possibly due to significant variation in the LAI, LAD and CGR. Further, the higher grain yield obtained with Deccan hybrid (59.3 q $ha^{-1}$) and Mexican june (59.1 q $ha^{-1}$) than Arabhavi local (40.3 q $ha^{-1}$) even with equal LAI of 2.5 at silking in all the three genotypes, lead to the opinion that LAI, LAD and NAR are not only the attributes associated with yield, but also the other yield determinants operating are deciding the yield capacity and yield expression of maize genotypes (Krishnamurthy *et al*., 1973a).

The yield potential of any genotype could be evaluated from its rate of dry matter production and its translocation at different stages of its growth. In general, the dry matter accumulation in maize plants is gradual and small during early stages of growth and rapid after 45 days after sowing till maturity. Krishnamurthy *et al*. (1973a) observed 0.5, 3.3 and 3.5 g $plant^{-1}$ $day^{-1}$ dry matter production at seedling, silking and grain filling stages respectively.

Further, noticed increased percent distribution of dry matter in leaves upto 15 days, in stem upto 45 days from sowing which then declined. The per cent distribution of dry matter in tassel, silk and cob sheath began initially low and reached a peak and declined at physiological maturity. While, per cent distribution of dry matter in cob increased linearly upto maturity.

The rate of dry matter production during *rabi* season at Dharwad differed significantly during all the growth periods except during 1 to30 days. The rate of dry matter accumulation in maize was lowest (1.016 g plant$^{-1}$ day$^{-1}$) at 1 to 30 days, increased to the maximum (4.1 g plant$^{-1}$ day$^{-1}$) at 61 to 90 days and later decreased (1.22 g plant$^{-1}$ day$^{-1}$) towards harvest (Setty, 1981). During 31 to 60 days and 91 days to harvest, EH-400175 recorded significantly higher rate of dry matter accumulation than G-2 composite and Arabhavi local, but on par with that of Deccan. During 61 to 90 days EH-400175 recorded significantly higher rate of dry matter accumulation during all the growth periods.

During winter season at Raipur, Madhya Pradesh, Manishkumar (1998) documented differences in dry matter accumulation due to genotypes. The study revealed that dry matter accumulation was similar during early stages, however differed at later stages namely 60$^{th}$ and 90$^{th}$ day and maturity. Among the genotypes under study PA hybrid recorded higher dry matter accumulation followed by Devika and RH-1. With this it was concluded that more dry matter accumulation and LAI of PA hybrid resulted in higher net assimilation rate, in turn recorded higher yield.

The differences in yield among genotypes were attributed not only to variations in growth parameters but also to yield attributes (Krishnamurthy *et al*., 1973a). The yield of maize is the function of plant height, length of cob, number of rows per cob, weight per cob and weight of stover (Singh, 1966; Halemani *et al*., 1980a; Halemani *et a.l*, 1980b).

Pande *et al*. (1971), while narrating the higher yield of Hy-2385 as compared to other 10 hybrids, clearly established the positive and significant correlations in plant height, number of grains per cob, yield of grain per plant and 1000 grain weight with yield. In a similar study Ramos *et al*. (1993) found linear relationship of these characters with yield.

The yield difference among genotypes was documented at Bangalore during *kharif* and summer seasons. The higher difference in yield due to genotypes in any one season was primarily attributed to greater mean grain weight cob$^{-1}$ and higher test weight (Krishnamurthy *et al*., 1972). During *kharif* and *rabi* seasons hybrids are preferred to that of other germplasms, because hybrids produced more number of cobs ha$^{-1}$ and more grain weight cob$^{-1}$ than the other germplams (Krishnamurthy *et al*., 1973a).

Rameswarsingh (1975) during *rabi* season in Bihar registered variation in grain yield among hybrids. Higher grain yield was recorded with Ranjit (52.1 q ha$^{-1}$) and Deccan (52.0 q ha$^{-1}$) as compared to that of Ganga-1 (39.3 q ha$^{-1}$) and Ganga-10 (34.q ha$^{-1}$).

Halemani *et al*. (1976) observed significant difference in grain yield among different genotypes during 1968 and 1969 at Arabhavi and 1970 at MRS, Dharwad. Similarly, Setty (1981) during *rabi* season under irrigated condition, found significant difference in grain yield among different genotypes. The study revealed that EH-400175 and Deccan gave significantly higher grain yield than G-2 composite and Arabhavi local. The higher grain yield of EH-400175 and Deccan was mainly due to their higher grain weight cob$^{-1}$, higher grain number cob$^{-1}$ and 1000 grain weight as compared to G-2 composite and Arabhavi local. Higher grain yield of EH-400175 than Deccan was mainly due to its higher grain weight plant$^{-1}$ and 1000 grain weight.

Alam (1995) revealed that hybrids resulted in better crop growth and yield than composites. Swamy and Swamy (1996) observed that maize hybrid DHM – 103 performed better with respect to growth, yield and yield attributes as compared to composites. In addition, significant difference in relation to plant and ear weight, 50 per cent silking and tasseling was recorded.

In another study at Dharwad and Kalloli, Gollar (1996) while comparing the performance of two genotypes narrated that Deccan-103 recorded 17 per cent higher yield than G-25 composite. The higher grain yield of Deccan-103 (6875 kg ha$^{-1}$) was attributed to higher values with respect to plant height, number of leaves, leaf area index, number of cobs plant$^{-1}$, number of grains cob$^{-1}$, grain weight and grain yield plant$^{-1}$ than composite G-25.

At Arabhavi, while assessing the performance of three full season genotypes during *rabi* season, it was observed that DMH-1 registered higher yield than Deccan-103 and Prabha composite. During 1991-92 *rabi*, DMH-1 recorded higher yield (7718 kg $ha^{-1}$) as compared to Deccan-103 (5949 kg $ha^{-1}$) and Prabha (5984 kg $ha^{-1}$). The increase in grain yield of DMH-1 over Deccan-103 and Prabha was 29.7 and 28.9 percent respectively. Similarly, during 93-94 *rabi*, DMH-1 registered higher yield (8884 kg $ha^{-1}$) than Deccan-103 (5050 kg $ha^{-1}$) and Prabha (4953 kg $ha^{-1}$), and DMH-1 recorded 17 and 11 per cent higher grain yield than Deccan-103 and Prabha respectively (Anon, 1996a). Over the seasons, locations and years, DMH-1 registered 15 per cent higher yield than other full season genotypes namely Deccan-103 and Prabha (Anon, 1996a; Patil *et al*., 2000).

In another study, during *rabi* season, the single cross hybrid DMH-2 out-yielded the other two hybrids namely DMH-1 and Deccan-103. The grain yield of DMH-2 was maximum (8408 kg $ha^{-1}$) during 1992 *rabi* and minimum (5247 kg $ha^{-1}$) during 1996. During the corresponding season, Deccan-103 recorded maximum of 6977 kg $ha^{-1}$ and a minimum of 4424 $kgha^{-1}$. Over the seasons, locations and years DMH-2 recorded 20.5 and 8.5 per cent higher grain yield than Deccan-103 and DMH-1, respectively (Patil *et al*., 2000).

The production potential of winter maize differs with different genotypes (Franca *et al*., 1990) and agro-ecosystems (Anon, 1994; Anon, 1995; Anon, 1996; Anon, 1997; Anon, 1998; Anon, 1999; Anon, 2000). The difference in yield was attributed to difference in growth and yield attributes (Sinha, *et al*., 1990; Prasad *et al*., 1990, Rehman *et al*., 1992, and Magalhaes *et al*., 1995).

## 2.2 EFFECT OF PLANTING DATES

The optimum sowing time provides the most optimum environmental condition for growth and yield of maize. The optimum sowing date for maize in India is more important in winter than in the monsoon/rainy season due to much variation in temperature during winter season (Singh and Zaidi, 1998). The maize crop grown under well-supplied water and nutrient conditions, the temperature and solar radiation reported to have greater effect on growth and development of crop (Muchow, 1989; Muchow *et al*., 1990; Cirilo and Andrade, 1994a; Cirilo and Andrade, 1994b).

### 2.2.1 Effect of temperature and solar radiation

The variation in sowing date in maize modifies the radiative and thermal conditions during its growth. The amount of incident radiation and its proportion that intercepted by the crop directly determines crop growth rate (Tollenaar and Bruulsema, 1988; Muchow *et al*., 1990). Temperature affects the duration of crop growth (Brown, 1977; Hardacre and Turnbull, 1986; Warrington and Kanemasu, 1983a), and consequently the time during which incident radiation can be intercepted and transformed to dry matter. Temperature also affects final leaf number (Hesketh *et al*., 1969; Tollenaar and Hunter, 1983; Stevenson and Goodman, 1972) and leaf canopy development (Tollenaar *et al*., 1979; Thiagarajah and Hunt, 1982; Hesketh andWarrington, 1989; Warrington and Kanemasu, 1983b) which define crop leaf area index, thereby determine the proportion of the incident radiation intercepted (Muchow and Carberry, 1989) by the crop and accumulation of dry matter. The grain yield improvement of maize hybrids appears to be the result of increased dry matter accumulation (Tollenaar, 1989). Moreover, low temperature reduced radiation use efficiency in maize (Carberry *et al*., 1989; Andrade *et al*., 1993). Increased accumulation of dry matter in hybrids after silking can be attributed to increased radiation use efficiency (Tollenaar and Anguilera, 1992).

Temperature very much affects the duration of crop growth (Allison and Daynard, 1979), and hence the maximum time that the incident radiation can be intercepted is of particular importance in the length of the grain filling period since the dry matter accumulated in the grain in maize is largely from dry matter that accumulates after flowering. The duration of grain filling decreased with increasing temperature, and the shorter grain-filling period often associated with lower grain yield (Hunter *et al*., 1977; Badu-Apraku *et al*., 1983). However, shorter duration of grain-filling due to higher temperature the grain yield unchanged due to coincidentally higher incident radiation at higher temperatures (Muchow, 1989).

## 2.2.2 Effect on growth and yield

The leaf area per plant was lower in early planting (14$^{th}$ September) as compared to later plantings (McCormic, 1974). Delayed sowing caused significant reduction in plant height (El-Sharkaway *et al*., 1975). A physiological study at Kenya by Cooper and Law (1971) indicated that crop growth rate progressively declined with delay in sowing, which resulted in smaller plants. Further, obtained strong relationship between the size of plant at tasseling and final grain yield.

A study on the effect of sowing dates under irrigated condition during *rabi* season at Dharwad revealed that the difference in grain and straw yield was mainly due to difference in growth and yield attributes among different sowing dates. Significant differences due to sowing dates (at 15 days interval from 15$^{th}$ September to 30$^{th}$ December) were observed in plant height, total dry matter and per cent dry matter distribution in different parts at different growth stages (at 30 days, 60 days and at harvest). Among the different sowing dates, higher growth and growth parameters were recorded at September 30$^{th}$ sowing followed by October 15$^{th}$ sowing. Further, significant difference in days to 50 per cent tasseling and silking was observed. Days to 50 per cent tasseling and silking increased significantly with every fortnight delay in sowing from 15$^{th}$ September to 30$^{th}$ November. Differences in days to 50 per cent tasseling and silking was attributed to difference in maximum and minimum temperature during growth periods. The difference in growth and development due to sowing dates manifested in difference in grain and straw yield. Significantly higher grain yield (69.45 q ha$^{-1}$) was obtained with 30$^{th}$ September sowing over other dates of sowing. Sowing earlier by a fortnight or later than 30$^{th}$ September resulted in significant decrease in grain and straw yield with every fortnight delay in sowing upto 15$^{th}$ November. Sowing on 15$^{th}$ October, which was next to 30th September, recorded significantly higher yield as compared to all later dates of sowing and 15$^{th}$ September sowing. The increase in grain yield on 30$^{th}$ September was 41 per cent as compared to 15$^{th}$ September sowing and 10, 24, 40, 35, 27 and 17 per cent as compared to later sowing dates namely 15$^{th}$ October, 30$^{th}$ October, 15$^{th}$ November, 30$^{th}$ November, 15$^{th}$ December and 30$^{th}$ December, respectively. Significantly higher grain yield with 30$^{th}$ September sowing as compared to earlier and all later dates of sowing could be related to higher grain weight cob$^{-1}$ mainly as a consequence of its higher grain number cob$^{-1}$. 1000 grain weight did not differ significantly due to dates of sowing. However, higher 1000 grain weight (262.75g) was observed with 30$^{th}$ September as compared to all other dates of sowing (Setty, 1981).

During winter, Singh *et al*. (1987) reported that two maize cultivars namely Pratap-1 and Ageti-76 sown on December 12$^{th}$ gave significantly higher grain yield than when sown on December 24$^{th}$ or January 2$^{nd}$ at Hissar. The reason attributed for higher yield was longer grain filling period in December 12$^{th}$ sowing.

A field experiment conducted during winter season at Ludhiana by Sawhney *et al*. (1989) revealed that the highest grain yield of 50.9 and 50.2 q ha$^{-1}$ was obtained from October and mid November sowing dates respectively, and yield declined with delayed sowing of mid-December (37.4 q ha$^{-1}$).

Nandal and Agarawal (1991) reported that the maize crop sown at Hissar on 2$^{nd}$ November recorded significantly higher dry matter accumulation, LAI and crop growth rate (CGR) upto 90 days after sowing as compared to 30$^{th}$ November sown crop.

A study conducted at Anand during *rabi* season (RajiReddy, 1991) showed marked difference in LAI and grain yield due to different sowing dates. The peak LAI of 5.1, 5.53 and 4.87 during 1989-90 and 4.37, 4.54 and 4.49 during 1990-91 was attained at 50, 50 and 60 days after emergence for October 5$^{th}$, October 20$^{th}$ and November 4$^{th}$ sowing dates, respectively. The difference in grain yield was non-significant during 1989-90 and significant during 1990-91. However, during 1989-90 the highest grain yield (52.75 q ha$^{-1}$) was recorded in October 20$^{th}$ followed by October 5$^{th}$ (50.75 q ha$^{-1}$) and lowest was with November 4$^{th}$ (46.32 q ha$^{-1}$). During1990-91, October 5$^{th}$ sowing recorded significantly higher grain yield (70.64 q ha$^{-1}$) as compared to October 20$^{th}$ (57.39 ha$^{-1}$) and November 4$^{th}$ (50.01 q ha$^{-1}$). The highest yield was mainly attributed to the increase in time taken from silk emergence to maturity or in other words prolonged grain filling period.

Sandhu and Hundal (1991) reported that, the emergence took 9,12 and 23 days and crop matured in 188, 133 and 176 days after sowing when sown in the first week of November, third week of November and first week of December respectively, and progressively declined maize yield with delayed sowings under Punjab conditions.

The changes in the environment that are associated with different sowing dates are expected to alter maize growth and development (Cirilo and Andrade 1994a). The effect of sowing dates (mid-September through mid December) revealed that delay in sowing date hastened development between seedling emergence and silking, decreasing cumulative incident radiation on the crop during the vegetative period. However, late sowings increased crop growth rate during the vegetative growth period because of high radiation use efficiency and higher percent radiation interception. Conversely, late sowings decreased crop growth rate during grain filling because of low radiation use efficiency and low incident radiation. Late sowing affected grain yield by decreasing kernel weight and kernel number per unit area. Moreover, maize subject to delayed sowing accumulated more dry matter before silking than from silking to physiological maturity, while the inverse was true for early sowings. Thus, delay in sowing strongly decreased dry matter partitioning to grain.

Further, the delay in sowing date affected final kernel number in maize by decreasing the number of ears and number of kernels per ear at harvest. Reduction in crop growth rate after silking determined to decrease in the number of ears. Decrease in number of ears are not associated with crop growth in the pre-silking period. Crop growth rate in pre-silking is important for allocation of assimilates to structural vegetative growth and maintenance respiration. Hence, decrease in crop growth rate in late sowings would be associated with high ear barreness ( Cirilo and Andrade, 1994b).

At Dholi, *rabi* maize sown at 15 days interval ( mid- November through mid- January) recorded significantly higher grain yield with 15$^{th}$ November as compared to other dates of sowing ( Anon, 1994).

Otegui *et al.*(1995) at Argentina, reported that on a silty clay loam soil, the maize crop grown between 20$^{th}$ August and 20$^{th}$ November at monthly interval under no water and/or nutrient restrictions, the shoot dry weight at physiological maturity was associated with amount of photosynthetical active radiation intercepted (IPAR). The radiation use efficiency before silking (4.14 g $MJ^{-1}$) was higher than after silking (2.45 g $MJ^{-1}$). Grain yield was correlated with shoot dry weight at physiological maturity, and it resulted in a stable harvest index. Shoot dry weight at silking recorded significant relationship with final grain number ($r^2$=0.52, n=32) as well as with grain yield ($r^2$=0.55, n=32).

The study conducted at Arabhavi, to know the response of genotypes to planting dates during *rabi* season (Anon, 1997) indicated that the ideal period for sowing *rabi* maize was between I$^{st}$ week of October to I$^{st}$ week of November. Among the different dates, October 15$^{th}$ and November 1$^{st}$ recorded significantly higher grain yield as compared to other sowing dates. Significant yield difference was also observed with different genotypes. Further, Singh and Zaidi (1998) suggested, October 15$^{th}$ to November 15$^{th}$ is the best dates for sowing *rabi* maize in Karnataka.

The ideal period of sowing of *rabi* maize at Ludhiana found to be between mid-October and last week of November. Any delay after November reduced the yield level significantly (Anon, 1998). Among different dates of sowing November 20$^{th}$ recorded highest grain yield (68.1 q $ha^{-1}$) followed by October 25$^{th}$ (63 q $ha^{-1}$), which were on par, whereas December 15$^{th}$ and January 10$^{th}$ recorded significantly lower yield of 58.8 q $ha^{-1}$ and 47 q $ha^{-1}$, respectively. Further, days taken to silking also varied due to sowing dates and genotypes. Among the genotypes JH-4193 recorded higher yield (71.69 q $ha^{-1}$) followed by JH-6804 (69.79 q $ha^{-1}$), JH-6698 (59.3 q $ha^{-1}$) as compared to Pratap (50.09 q $ha^{-1}$) and JH-6845 (45.5 q $ha^{-1}$). In a similar study, the *rabi* maize yield differed significantly due to planting dates and genotypes (Anon, 2000). The October 30$^{th}$ sowing recorded higher grain yield (69.67 q $ha^{-1}$) as compared to November 15$^{th}$ (65.25 q $ha^{-1}$) and October 15$^{th}$ (53.58 q $ha^{-1}$).

## 2.3 EFFECT OF IRRIGATION SCHEDULING

The increase in frequency of irrigation increased the plant height (Shalaby and Mikhail, 1979; Prasad and Prasad, 1992). Prasad *et al.* (1985) noted significantly higher plant height (135.0 cm) at 1.0 IW/CPE ratio irrigation scheduling than at 0.8 (127.6 cm) and 0.6 (116.2 cm) IW : CPE ratios. Increase in irrigation level from 0.5 to 0.9 IW/CPE ratio resulted in significant increase in plant height of maize (Palled *et al.* 1991).

The dry matter production of maize increased with increase in IW:CPE ratio from 0.6 to 1.2 (Khera *et al.*, 1976). Prasad *et al.* (1985) found that dry matter plant$^{-1}$ increased significantly (from 39.21 to 52.20 g plant$^{-1}$) when IW:CPE ratio increased from 0.6 to 1.0. Increasing irrigation frequency (Bajwa, *et al.*, 1987) and level of irrigation (Kasele *et al.*, 1994) increased dry matter yield. Balaswamy *et al.* (1978) narrated that increased soil moisture depletion decreased the number of functional leaves per plant. Decrease in leaf number per plant observed with increasing in soil moisture depletion (El-Sharif-Wa *et al.*, 1986). Water stress conditions during vegetative growth (30 to 48 DAS) resulted in decreased leaf area (Sabrado, 1990). More frequent irrigation at 0.8 and 1.0 IW/CPE ratio caused increase in leaf are index and produced higher grain yield (Prasad and Prasad, 1989). Moisture deficit reduced leaf longevity, green leaf area and turgor from anthesis to harvest (Wolfe *et al.*, 1988). Dry matter production in stem and leaves shown slow growth upto 56 days and increased rapidly and almost linearly thereafter (Galbiatti *et al.*, 1989). At Varanasi, during winter season leaf area plant$^{-1}$, leaf area index, dry weight of leaves, stem, sheath and ear increased as a result of increased frequency of irrigation from 0.6 to 0.8 IW/CPE ratio with 6 cm depth of water for maize crop (Sridhar and Singh, 1989).

Irrigation scheduling with increased IW/CPE ratios from 0.4 or 0.5 to1.0 or 1.2 increased the number of cobs plant$^{-1}$ (Roy and Tripathi, 1987; Puste and Kumar, 1988; Jadhav *et al.*, 1992). Whereas, increase in irrigation scheduling from 1.0 to 1.2 decreased the cob number (Shridhar *et al.*, 1991a). However, Mehrotra *et al.* (1968) reported non significant effect on cob number plant$^{-1}$ with irrigation from 0.15 to 0.75 atm tension.

The test weight increased by 10.6 and 12.6 per cent with irrigation application at 1.2 IW/CPE ratio (6 irrigations) as compared to 0.8 IW:CPE ratio (4 irrigations) and 0.6 IW/CPE ratio (3 irrigations) (Cheema and Uppal, 1987). Prasad and Prasad (1988) observed higher thousand grain weight (331 g) with 0.80 IW/CPE ratio as compared to 0.6 and 0.4 IW/CPE ratios. Narang *et al.* (1989b) reported higher thousand grain weight (231.9 g) at 75 mm CPE irrigation as compared to others (100, 125, 150, 175 and 200 mm). However, Shridhar *et al.* (1991a) reported decrease in thousand grain weight with irrigation applied beyond 1.00 IW/CPE ratio. Letatulu *et al.* (1998) reported that no stress with frequent irrigation at all stages 1.0 IW/CPE ratio resulting in significantly higher test weight and inturn higher grain yield.

Roy and Tripathi (1987) observed that the grain weight cob$^{-1}$ increased significantly with increasing irrigation schedule from 0.5 to 0.9 IW/CPE ratios. Kalaghatagi *et al.* (1988) reported higher grain weight cob$^{-1}$ at 0.8 IW/CPE ratio as compared irrigation at 0.5 and 0.4 IW/CPE ratios. Similar observations were also made by Prasad and Prasad (1988); Nandal and Agarawal (1989); Narang *et al.* (1989a) and Bajwa *et al.* (1987). Shridhar *et al.* (1991a) found significant increase in cob length at 1.0 IW/CPE ratio. Vosic and Videnovic (1980) recorded that irrigation frequency had no effect on cob diameter. Similar observations were also made by El-Sharif-wa *et al.* (1986) and Shridhar *et al.* (1991b).

Sridhar and Singh (1989) reported that irrigation at 1.0 IW/CPE ratio resulted in significant increase in grain rows cob$^{-1}$ and number of grains row$^{-1}$ over 0.8 and 0.4 IW/CPE ratios. On the other hand, Nandal and Agarawal (1989) observed significant effect on shelling percentage due to increased number of irrigations. Similar results were reported by Bari *et al.* (1980) and Mohmed (1984).

Significant increase in grain and stover yield of maize was obtained with increase in IW:CPE ratios from 0.6 to 1.0 (Prasad *et al.*, 1985; Jadhav *et al.*, 1987 and Prasad *et al.*, 1987). Roy and Tripathi (1987) reported yield reduction by 23 per cent at 0.5 IW:CPE ratio as compared to 0.9 IW/CPE ratio. Cheema and Uppal (1987) observed that irrigation scheduling at 1.2 IW:CPE ratio (6 irrigations) significantly increased the grain yield by 34.5 and 35 per cent over 0.8 (4 irrigations) and 0.6 IW:CPE ratios (3 irrigations), respectively. In other studies, higher maize yield was obtained by scheduling irrigation at 0.8 IW : CPE ratio than 0.6 and 0.4 IW:CPE ratios (Prasad and Prasad, 1988; Kalaghatagi, *et al*., 1990). Sridhar and Singh (1989) reported that increasing IW:CPE ratio from 0.6 to 1.0 increased the grain yield from 2.14 to 3.12 t $ha^{-1}$, respectively. In a similar study, Shridhar *et al*., (1991a) recorded grain yield of 2.14, 2.40, 3.12 and 3.0 t $ha^{-1}$ with IW:CPE ratios of 0.6, 0.8, 1.0 and 1.2, respectively. Similar trend in yield increase was observed with increase in frequency of irrigation (Nandal and Agarawal, 1989).

The grain yield increased from 4.63 to 14.07 t $ha^{-1}$ with increase in irrigation from zero irrigation to 4 irrigations, but yield reduced by 3.8 to 10.8 per cent by omitting the I, II, III or IV irrigations (Panchanathan *et al*., 1992). Simon (1991) was also of a similar opinion. Prasad and Prasad (1992) reported that 0.8 IW:CPE ratio resulted in higher grain yield (48.4 q $ha^{-1}$) as compared to 0.4 and 0.6 IW/CPE ratio. Jadhav *et al*. (1993) reported that grain yield of maize increased linearly from 4.23 to 5.29 t $ha^{-1}$ when IW:CPE ratio increased from 0.4 to 1.0. In similar studies increase in irrigation scheduling from 0.6 to 1.0 IW:CPE ratio increased the stover yield of maize (Jadhav, *et al*., 1992). Alam (1995) and Letatulu *et al*. (1998) revealed that the highest grain yield obtained at 1.0 IW:CPE ratio. Bandyopadhyay and Mallick (1996) recorded grain yield of 2.22, 1.85 and 1.77 t $ha^{-1}$ with the IW:CPE ratios of 1.2, 0.9 and 0.6, respectively. Varughese and Iruthayaraj (1996) found highest yield at 0.75 IW:CPE ratio, whereas Singh *et al*. (1997) found highest yield with 1.2 IW:CPE ratio. Manishkumar (1998) proved that irrigation schedule with 1.0 IW:CPE ratio (5 irrigations) at 34, 69, 84, 97 and 107 days after sowing was better in terms of growth, yield and yield attributes than lower frequency at 0.7 IW:CPE ratio (3 irrigations) at 44, 83 and 101 days.

The water requirement of sweet corn ranged from 311 to 604 mm under siltyclay loam (Braunworth, 1987). Similarly in another study, the water used was 481 mm as estimated by soil-water balance equation (Braunworth and Mack, 1987). Bowman *et al*. (1991), stated that the water requirement of maize was generally in accordance with evaporative demand and rainfall. Jadhav *et al*. (1994), revealed that the water consumption of maize was 436.33 to 414.41 mm at 0.4 to 0.6 IW:CPE ratios in Maharashtra under clay loam soil. Similarly in another study, maize water need was 30.4 cm during summer season in silty clay loam soil at 0.75 IW/CPE ratio with higher yield (Khan *et al*., 1996).

Mallikarjunaswamy (1997) reported 519.8 mm water use at 0.8 IW:CPE ratio irrigation scheduling as compared to 469.8 mm at 0.6 IW:CPE ratio. Similarly Letatulu *et al*. (1998) reported that total water requirement of maize ranged from 45.10 to 60.10 cm depending on irrigation scheduling at Bangalore conditions during summer, irrigation at IW:CPE ratio of 1.0 throughout the crop growth period resulted in higher yield with highest water use of 60.1 cm and WUE of 126.89 kg $ha^{-1}$ $cm^{-1}$.

Roy and Tripathi (1987) reported inverse relationship between irrigation and water use efficiency. Aujla *et al*. (1987) reported that mean WUE decreased (from 51 to 44 kg $ha^{-1}$ $cm^{-1}$) with increasing application of irrigation water (from 25.0 to 49.5 cm). Pillai *et al*. (1990) found that mean water use efficiency decreased with increasing irrigation levels (from 25 to 75 per cent available moisture). Palled *et al*. (1991) reported that water use efficiency decreased with irrigation applied beyond 0.7 IW:CPE ratio. Prasad and Prasad (1992) found highest water use efficiency (351 kg $ha^{-1}$ $cm^{-1}$) under 0.4 IW:CPE ratio followed by 0.6 and 0.8 IW:CPE ratio. Jadhav *et al*. (1992) found that water use efficiency increased (from 12.1 to 17.0 kg $ha^{-1}$ $cm^{-1}$) with decreased IW:CPE ratio from 1.0 to 0.4.

In contrast, Prasad *et al*. (1985) reported increased water use efficiency (from 135.6 to 150.2 kg $ha^{-1}$ $cm^{-1}$), with increasing IW:CPE ratio (from 0.5 to 0.9). Similarly, Cheema and Uppal (1987) recorded increased water use efficiency from 48.5 to 53.3 kg $ha^{-1}$ $cm^{-1}$ with increased number of irrigations.

Varughese and Iruthayaraj (1996) observed higher water use efficiency at IW:CPE ratio of 0.75. Similarly, Bandyopadhyay and Mallick (1996) reported WUE of 7.25, 6.41 and 6.32 kg $ha^{-1}$ $mm^{-1}$ for IW:CPE ratio of 1.2, 0.9 and 0.6 respectively in winter maize. Kumar and Bangarwa (1997) found that water stress created at early stage caused more extraction of water from deeper soil layers. Moisture stress at silking and dough stages decreased the water use efficiency of maize. Silking stage was found to be most sensitive to water stress.

## 2.4 EFFECT OF PLANT DENSITY

Variation in plant density found to affect the growth and yield due to differential availability of light, moisture and nutrients. The grain yield of maize per unit land area is highly dependent upon plant population, plant distribution, fertility level and growth characteristics of the genotypes adopted to that area. The major limiting factors to yield appear to be leaf area, its manner of display and $CO_2$ supply (Loomis and Williams, 1963). Competition among plants due to increase in plant population will result in reduction of leaf area (Eik and Hanway, 1965) and yield of grain plant$^{-1}$ (Prine and Schroder, 1964; Warren, 1963). Nunez and Kamprath (1969) noticed linear reduction in leaf area plant$^{-1}$ due to increased plant population from 34,500 to 69,000 plants ha$^{-1}$. And concluded that leaf area index increased with increasing plant population. Alessi and Power (1975) observed maximum LAI at high plant population level (74,000 plants ha$^{-1}$) in all the three years of their study.

Iwata and Okuba (1971) showed that at the time of silking in fertile soil, the LAI of 4 to 6 was sufficient to maximize grain yield. Even with the increase in LAI above 6, the amount of dry matter production plant$^{-1}$ after flowering has not shown great improvement. Under such conditions, the photosynthates available were insufficient to develop all the kernels (Allison, 1969). With increase in plant population, Iwata (1975) observed smaller leaf area plant$^{-1}$ with thinner leaves. The leaf area reduced from 8068 sq.cm plant$^{-1}$ to 7095 sq.cm plant$^{-1}$ with increase in plant population from 40,000 to 1,00,000 plants ha$^{-1}$.

Krishnamurthy *et al*. (1973a) obtained decreased dry matter accumulation and distribution with increase in plant population. And, noticed increased LAI, decreased leaf area plant$^{-1}$ with increase in plant population from 55000 to 83000 plants ha$^{-1}$. Further increase in plant population resulted in higher LAI (Eik and Hanway, 1965) and delayed maturity in maize (Sharma and Gupta, 1968).

Bunting (1966) reported that dry matter production plant$^{-1}$ in maize was linearly related to the logarithm of space available. Crossman (1967) reported that increased crop density decreased individual plant weight owing to the fall in total assimilatory leaf area.

Krishnamurthy *et al*. (1974) recorded slight decrease in leaf area plant$^{-1}$ (from 4850 to 4390 sq.cm) and significantly increased LAI (from 2.7 to 3.7) with increased plant population from 55000 to 83000 plants ha$^{-1}$. Further stated that the slight increase in grain yield as a result of slight increase in plant population might be due to increased LAI and LAD although there were slight decrease in NAR and RGR.

Sharma and Gupta (1968) noticed significantly delayed silking (75%) due to increased plant population (60000 to 70000 plants ha$^{-1}$) as compared to 40000 plants ha$^{-1}$. Similarly Beech and Basinski (1975) observed delay in silking with increase in plant population from 44500 to 89000 plants ha-$^{1}$ in both early and late maturing maize genotypes. At Darwad, Setty (1981) revealed that days to 50 per cent tasseling and silking differed significantly due to plant densities. Every increase in plant density from 60,000 to 1,00,000 plants ha$^{-1}$ significantly increased the days for tasseling (58 to 61 days) and silking (65 to 68 days).

Termunde *et al*. (1963), under irrigated conditions obtained increase in grain yield of maize with increase in population from 12000 to 60000 plants ha$^{-1}$, further increase in population to 80000 plants ha$^{-1}$ decreased the grain yield. Sharma and Gupta (1968) noticed increase in grain yield of maize from 45.65 q ha$^{-1}$ to 51.97 q ha$^{-1}$ with increase in population from 40,000 to 60,000 plants ha$^{-1}$. Further increase in population to 70,000 plants ha$^{-1}$ decreased the yield. Nunez and Kamprath (1969) recorded increase in grain yield with increase in plant population from 34,500 to 51,750 plants ha$^{-1}$. Similarly, Nageswarareddy and Kaliappa (1974) reported that the increase in plant population from 41,000 to 83,000 plants ha$^{-1}$ increased the grain yield from 54.66 to 76.28 q ha$^{-1}$.

Verma and Singh (1976) studying the response of maize to nitrogen levels, moisture regimes and plant density found that increase in plant population from 60,000 to 85,000 plants ha$^{-1}$ increased the grain yield from 23.5 to 34.0 q ha$^{-1}$. Plant population is one of the most important factor influencing fodder yield. Crop production researchers have conducted many studies on plant competition to determine the optimum plant population density for maize (Olsen and

Sander, 1988), and reported that fodder yield increased with increasing plant population (Termunde *et al*. 1963; Goydani and Singh, 1968; Prithviraj *et al*., 1975; Nageswarareddy and Kaliappa, 1974; Setty, 1981; Singh *et al*., 1997).

Many plant density investigation results have indicated that increase in plant population decreased the grain yield plant$^{-1}$, ear weight, ear length, ear girth, number of grains ear$^{-1}$ and 1000 grain weight (Nanpuri, 1960; Stickler, 1964; Singh, 1967; Goydani and Singh, 1968; Brown *et al*., 1970; Setty, 1981; Singh *et al*., 1997). Sharma and Gupta (1968) reported that increase in plant population from 40,000 to 70,000 plants ha$^{-1}$ increased the number of barran plants ha$^{-1}$ and total ears ha$^{-1}$ significantly. The grain yield cob$^{-1}$ decreased with increasing plant population.

Tripathi (1971) noticed slight but not significant reduction in test weight with increase in plant population. Boltan (1971) obtained considerable decrease both in size of cob and weight cob$^{-1}$ with increase in plant population. Alessi and Power (1974) observed increased number of barren plants and decreased ear weight with increase in plant population from 20,000 to 74,000 plants ha$^{-1}$. Nageswarareddy and Kaliappa (1974) reported that though, the individual cob weight was less at 83,000 plants ha$^{-1}$, more number of cobs ha$^{-1}$ contributed to higher grain yield in Deccan hybrid maize. Rathore and Singh (1976) found negative effects on stem thickness, barren plants, ear length, thickness and weight, grains ear$^{-1}$, test weight and shelling percentage due to increase in plant population.

Setty (1981) in Dharwad conditions reported that the grain yield of maize increased significantly with increase in plant density from 40,000 to 80,000 plants ha$^{-1}$. The response of grain yield to increased plant density was quadratic for Deccan, EH-400175 and Arabhavi local genotypes. The maximum grain yield of Deccan, EH-400175 and Arabhavi local was found to be at 93,800, 1,09,813 and 2,07,540 plants ha$^{-1}$, respectively. And found that the difference in grain yield under varying plant densities was attributed to the difference in yield attributes. The individual plant performance was superior at low plant density as compared to high plant density. The grain weight plant$^{-1}$ and grain weight cob$^{-1}$, number of grains cob$^{-1}$ and 1000 grain weight revealed that there was significant increase with decrease in plant density. This was attributed to differences in total dry matter production plant$^{-1}$. Further, reported that straw yield increased significantly with increase in plant density. The total nitrogen uptake showed significant increase with increase in plant density.

Reddy *et al*. (1987) studied the effect of plant density on grain yield of maize and found that grain yield increased significantly with increase in plant density from 40000 to 100000 plants ha$^{-1}$.

Modern hybrids tolerate high plant density stress more than older hybrids. The modern hybrids compared to older hybrids respond more favourably to high plant densities in part because of a high leaf area index (LAI) at silking, which resulted in more interception of photosynthetically active radiation and more dry matter accumulation during vegetative development (Tollenaar and Anguilera, 1992). Cox (1996) reported that low plant density (4.5 plants m$^{-2}$) recorded 15 per cent lower dry matter and grain yield than high plant density (9 plants m$^{-2}$).

Gollar (1996) noticed that application of 200 per cent recommended NPK fertilizer (300:150:75 kg NPK ha$^{-1}$) with increase in plant density upto 111111 plants ha$^{-1}$ was found to increase the grain yield (7103 kg ha$^{-1}$) by 34 per cent over recommended density of 55555 plants ha$^{-1}$ (5302 kg ha$^{-1}$).

During winter season, Singh *et al*. (1997) recorded significant yield variation due to different plant population under irrigated conditions. Significantly higher grain yield was recorded under 83333 plants ha$^{-1}$ than rest of the plant populations such as 111111, 66667 and 55556 plants ha$^{-1}$. The yield variation due to variation in plant population was attributed to variation in growth and yield parameters. Further, they obtained maximum number of grain row$^{-1}$, grain cob$^{-1}$, grain weight cob$^{-1}$, test weight and shelling percentage under 55556 plants ha$^{-1}$ followed by 66667, 83333 and 111111 plants ha$^{-1}$. Better performance under low plant density was attributed to lesser competition among the plants for the resources. Further, Singh and Zaidi (1998) concluded that for winter maize a population of 90,000 plants ha$^{-1}$ at harvest is desirable for realizing higher grain yield.

Madarres *et al*. (1998), while evaluating different genotypes under low (6.5 plants $m^{-2}$) and high (9.0 plants $m^{-2}$) plants densities reported that high yield potential was obtained with genotypes with rapid maturity, reduced stature of plants because these plants were more tolerant to the high plant density.

## 2.5 EFFECT OF NITROGEN

Nitrogen is essential for maize growth and yield, and N deficiency will decrease maize yield substantially. As most of the soils in India are deficient in nitrogen, several experiments results have shown good response to the applied nitrogen.

Many of the experimental results have indicated that plant height increased with increase in level of nitrogen application. The increase in plant height depends on factors like soil nutrient supply, genotypes and weather conditon. Under irrigated or adequate rainfall condition increasing the level of nitrogen increased the plant height (Sharma, 1973; Rajagopal and Morachan, 1974; Halemani *et al*., 1976; Halemani *et al*., 1980a; Setty, 1981; Manishkumar, 1998). Halemani *et al*. (1980a) observed that plant height of maize increased from 130 to 193 cm with increase in nitrogen level from zero to 240 kg $ha^{-1}$. Similarly, Setty (1981) recorded increase in plant height from 190 to 201 cm with increase in nitrogen from 60 to 180 kg $ha^{-1}$. Manishkumar (1998) also recorded similar trend, plant height increased from 203 to 233 cm with increase in nitrogen from 30 to 150 kg $ha^{-1}$.

Nunez and Kamprath (1969) opined that the grain yield $plant^{-1}$ depends upon the leaf area $plant^{-1}$. The efficiency of a given leaf area to produce grain was higher as nitrogen rate increased. As the leaf area index (LAI) increased upto 3.5, the relative yield with given rate of nitrogen was greater. Krishnamurthy *et al*. (1974) noticed slight increase in the LAI at silking (3.1 to 3.4) with increase in nitrogen from 100 to 200 kg $ha^{-1}$. Increase in the nitrogen level resulted in gradual decrease of LAI indicating gradual senescence as compared to sudden decline at low nitrogen level. Setty (1981) recorded increase in LAI (3.24 to 3.51) with increase in nitrogen dose (75 to 225 kg $ha^{-1}$). Similarly Manishkumar (1998) noticed increase in LAI from 2.77 to 3.43 with increase in nitrogen from 30 to 150 kg $ha^{-1}$.

Hanway (1962a) noticed linear increase in the rate of dry matter production in maize over a major part of the growing season at all fetility levels. The actual rate of dry matter accumulation was markedly affected by soil fertility differences. The highest growth rate was obtained when the plants had an adequate supply of nutrients with a daily dry matter production of 245 kg $ha^{-1}$ $day^{-1}$. Further, under P and K deficiency conditions these values were 204 and 200 kg $ha^{-1}$ $day^{-1}$ respectively. Under extremely N deficient condition, the rate of dry matter production was much lower and it was 82 kg $ha^{-1}$ $day^{-1}$. These differences were reflected in the final weight of each plant part, but not in the relative proportion of each plant part (Hanway 1926b, Krishnamurthy *et al*. (1973a) observed increase in dry matter accumulation and distribution $plant^{-1}$ with increase in the level of nitrogen. Ahlawat *et al*. (1975) reported that increasing nitrogen levels from 0 to 300 kg $ha^{-1}$ increased the dry matter accumulation upto 90 to 95 days after sowing, while in nonitrogen treatment dry matter accumulation ceased after 70 to 80 days after sowing. The total dry matter production $plant^{-1}$ differed significantly due to nitrogen levels. Every increase in nitrogen level from 75 to 225 kg $ha^{-1}$ increased the dry matter production from 266 to 323 g $plant^{-1}$ (Setty, 1981). Similar trend was observed by Manishkumar (1998).

Rai (1961) noticed early tasseling, silking and maturity by 9 to 16 days with application of 88 kg N $ha^{-1}$ as compared to no-nitrogen application. Sharma and Gupta (1968) observed significantly less days for silking with application of 150 to 200 Kg N $ha^{-1}$ over no nitrogen application. Shah *et al*. (1971) reported that increasing levels of nitrogen application reduced the days to silking. Mandloi *et al*. (1972) noticed 6 to 10 days early silking with application of 160 kg N $ha^{-1}$. Similarly many other workers have reported that increase in nitrogen level had reduced the days to silking significantly (Sharma, 1973; Halemani *et al*., 1976; Rathore and Singh, 1976; Shukla and Bharadwaj, 1976; Halemani *et al*., 1980a; Halemani *et al*., 1980b). In another study, Setty (1981) noticed significant difference in days to tasseling and silking due to nitrogen levels.

Application of nitrogen appreciably increased the yield and yield components such as length of the ear, girth of the ear, ear weight, grain weight ear$^{-1}$, 1000 grain weight and number of grain ear$^{-1}$ (Rai, 1961; Singh, 1967; Goydani and Singh 1968; Sharma *et al*., 1969; Tripathi, 1971; Sharma *et al*., 1979; Setty 1981; Manishkumar, 1998).

Sharma and Gupta (1968) obtained 52.5 per cent barren plants with no-nitrogen and this was reduced to 21.0, 10.7, 8.3 and 6.5 per cent when 50, 100, 150 and 200 kg N ha$^{-1}$ was applied respectively. Shukla and Bharadwaj (1976) reported that increasing nitrogen level from 30 kg ha$^{-1}$ to 90 kg ha$^{-1}$ significantly reduced the per cent barreness from 21.5 to 10.8 percent. Sharma *et al*. (1979) studied the response of 10 genotypes to nitrogen levels and over the seasons concluded that the barrenness varied with nitrogen levels and planting seasons. They found that the barreness varied between 18.2 and 34.6 percent with no nitrogen application, which had reduced to 2.7 and 10.9 per cent with application of 180 kg N ha$^{-1}$ during 1974 and 1975 planting seasons respectively. Halemani *et al*. (1980a) noticed increase in number of ears ha$^{-1}$ from 43,000 with no nitrogen to 57,000 at 240 kg N ha$^{-1}$. Setty (1981) also observed similar trend that increasing the nitrogen level from 60 to 180 kg ha$^{-1}$, and 75 to 225 kg ha$^{-1}$ reduced the barren plants from 4623 to 2540, and 2403 to 949 plants ha$^{-1}$ respectively.

Shah *et al*. (1971) noticed linear response to nitrogen application upto 180 kg N ha$^{-1}$. The better response to nitrogen application was attributed to decrease of barren plants with increase in nitrogen levels. Rajendraprasad and Turkhede (1971) reported that increase in nitrogen level from 0 to 180 kg ha$^{-1}$ increased the grain yield of maize.

Krishnamurthy *et al*. (1973 a) reported that the nitrogen level of 180 and 120 kg N ha$^{-1}$ appeared to be optimum for Deccan hybrid (65 q ha$^{-1}$) and Arabhavi local (45 q ha$^{-1}$) respectively.

Gupta (1975) obtained linear response to nitrogen application upto 240 kg ha$^{-1}$ during *rabi* season. The average response for 0 to 80, 80 to 160 and 160 to 240 kg N ha$^{-1}$ was 22.6, 14.5 and 9 kg grain kg$^{-1}$ of N applied respectively. Barthakur *et al*. (1975) reported that increase in nitrogen level from 0 to 160 kg ha$^{-1}$ increased the grain yield from 35.4 to 66.9 q ha$^{-1}$. In *rabi* season, Kumaraswamy *et al*. (1975) noticed increase in grain yield of Deccan hybrid from 33.3 q ha$^{-1}$ to 57.2 q ha$^{-1}$ with increase in nitrogen from zero to 180 kg ha$^{-1}$ .

From three years experiments conducted at Dharwad, Halemani *et al*. (1976) reported that maize yield increased significantly with increase in nitrogen level from zero to 240 kg ha$^{-1}$. Sharma *et al.* (1979) observed grain yield increase with increase in the level of nitrogen upto 180 kg ha$^{-1}$. Halemani *et al*. (1980a) reported that the mean grain yield which was 17 q ha$^{-1}$ with no nitrogen application increased to 42.1, 57.9 and 65.1 q ha$^{-1}$ with 80, 160 and 240 kg N ha$^{-1}$ respectively.

Setty (1981) recorded significantly increased grain yield at high nitrogen level over medium and low nitrogen levels by 16.32 and 62.77 per cent and, 17.79 and 75.38 per cent for every step increase in nitrogen level from 60 to 180 kg ha$^{-1}$ and 75 to 225 kg ha$^{-1}$ respectively. This increase in grain yield at higher nitrogen level was attributed to the favourable effect of nitrogen on yield components such as grain weight plant$^{-1}$, grain weight cob$^{-1}$, number of grains cob$^{-1}$, 1000 grain weight and reduced number of barren plants. The author further stated that, the response of grain yield to increased nitrogen levels was quadratic; the economic optimum level of nitrogen for Deccan, EH-400175 and G-2 composite was 310.48, 241.07 and 218.40 kg N ha$^{-1}$respectively.

Harold (1984) reported that highest yield of maize was obtained by applying 210 and 280 kg N ha$^{-1}$, yield response decreased when the amount of N fertilizer applied beyond or lesser than these levels. Further, noticed that plants removed most or all of the applied N from N rate at 140 kg N ha$^{-1}$, but increasing amounts of residual N were present as N rates increased from 210 through 350 kg ha$^{-1}$. Nandal and Agarawal (1989) found that increasing N rates from 0 to 200 kg ha$^{-1}$ increased the yield from 1.18 to 5.35 t ha$^{-1}$. Further, Ionescu *et al.* (1988) reported that grain yield ranged from 4.70 t ha$^{-1}$ with no N to 10.79 t ha$^{-1}$ with 240 kg N ha$^{-1}$. Singh and Sharma (1989) reported that application of 120 kg N ha$^{-1}$ recorded maximum seed yield of maize. Simon (1991) revealed that maize production increased by 20 per cent at 100 kg N ha$^{-1}$ which was considered adequate for light soils. Ernani *et al*. (1996) found that the amount of N necessary to promote maximum grain yield of 7.5 t $ha^{-1}$ was 102 kg $ha^{-1}$.

Similarly at Hissar, Bangarwa *et al*. (1992) noted that application of 180 kg N $ha^{-1}$ produced the highest grain yield (72.7 q $ha^{-1}$) of winter maize. They reported 222 kg N $ha^{-1}$ as optimum dose of N for winter maize. Ahmed (1992) reported that 192 kg N $ha^{-1}$ was optimum for obtaining good seed yield of maize.

Selvaraju and Iruthayaraj (1994) stated that seed yield was highest with 175 kg N $ha^{-1}$ as compared to 75 and 125 kg $ha^{-1}$. Varughese and Iruthayaraj (1996) reported that in the first year, maximum grain yield of maize was obtained at 156 kg N $ha^{-1}$, whereas, in the second year it was maximum with 187.5 kg N $ha^{-1}$ at Coimbatore.

Singh *et al*. (1965) obtained significant increase in stover yield with application of 201.6 kg N $ha^{-1}$ as compared to no-nitrogen application and application of 67.2 and 134.4 kg N $ha^{-1}$. Nageswarareddy and Kaliappa (1974) observed increase in straw yield from 67.36 q $ha^{-1}$ to 107.96 q $ha^{-1}$ with increase in level of nitrogen from zero to 150 kg $ha^{-1}$.

Cox *et al*. (1993) reported that the dry matter yield varied between 1991 (12.3 t $ha^{-1}$) and 1990 (16.9 t $ha^{-1}$) seasons and responded curvilinear to N rates (0, 56, 140, 160 and 225 kg N $ha^{-1}$) with recording maximum economic yield at 140 and 160 kg N $ha^{-1}$ respectively. The higher N rates increased the residual soil $NO_3$-N concentrations in the upper 0.3m soil depth in silt loam soil during 1990 (0, 3, 30 and 32 mg $kg^{-1}$) and 1991 (0, 0, 17, and 17 mg $kg^{-1}$) for the 0, 56, 140 and 225 kg N $ha^{-1}$ applications respectively.

Biomass production and nitrogen uptake by maize was studied by Zhou *et al*. (1997) on fine sandy loam by applying 0, 180, 270 kg N $ha^{-1}$. The results revealed that dry matter production and N uptake were much greater for treatment that received N fertilizer than zero N application. There were no differences in dry matter production or N uptake for the applied N rates of 180 and 270 kg N $ha^{-1}$. Therefore, it was reported that if the applied N exceeded 180 kg N $ha^{-1}$ it would result in lower N recovery, leading to increase in N accumulation in the soil profile.

## 2.6 CROP SIMULATION MODELS

Crop simulation models have been used widely to describe systems and processes at the level of genotype, the crop, the farming systems, the region and the global environment (Matthews *et al*., 2002). These models were originally developed as research tools and probably had their greatest usefulness so far as part of the research process.

Seligman (1990) stated the advantages of integrating simulation modeling approach into a research programme and listed the following uses of models in research: identification of gaps in our knowledge, generation and testing of hypothesis, and an aid to the design of experiments, determination of the most influential parameters of a system (sensitivity analysis), provision of a medium for better communication between researchers in different disciplines, and bringing researchers, experimenters, and producers together to solve common problems.

Boote *et al*. (1996) saw that models providing structure to a research programme and as being particularly valuable for synthesizing research understanding and for integrating up from reductionist research process, but pointed out that if the efficiency of research is to increase, then the modeling process must become a truly integrated part of the research activities. Experimentation and model development need to proceed jointly, new knowledge is used to refine and improve models, and models used to identify gaps in our knowledge, thereby setting research priorities. Sinclair and Seligman (1996) made a similar point, seeing models as a way of setting our knowledge in an organized, logical and dynamic framework, thereby allowing identification of faulty assumptions and providing new insights. Further, Matthews and Stephens (1998) narrated the use of models to provide new insights into crop processes and the focus of future research.

The crop models, not only used as tools in research, but there have been many attempts in recent years to use them as tools to help in decision making processes of practitioners with the development of so called decision support systems. The decision support system in a sophisticated form is an interactive computer system that utilizes simulation models, databases, and decision algorithms in an integrative manner and typically have quantitative output and place emphasis on the end user for final problem solving and decision making (Sprague and Carlson, 1982). Decision support systems have evolved over the years from rudimentary single decision tools to multiple criteria optimization. Matthews *et al*. (2002) while describing the applications of soil/crop simulation models narrated several examples of models being used both in research and in decision support.

The Decision Support System for Agro technology Transfer (DSSAT), a micro-computer software package that contains crop-soil simulation models, database for weather, soil and crops, and strategy evaluation program integrated with a 'shell' program which is the main user-interface. The DSSAT provides a framework for scientific co-operation through research to enhance its capabilities and apply it to research questions. It also has considerable potential to help decision makers by reducing the time and human resources for analyzing complex decision alternatives (Jones *et al*., 1998). The original DSSAT v 2.1 was released in 1989 by IBSNAT. A second release of DSSAT v 3.0 was made available late in 1994 (Tsuji *et al*., 1994). The DSSAT v 3.5 was made available for use during the year 1998 (Hoogenboom *et al*., 1999). These DSSAT have been used widely in both developed and developing countries as research and decision making tools. (Algozin *et al*., 1988; Jagtap *et al*., 1993; Lal *et al*., 1993; Singh *et al*., 1993; Bowen and Wilkens, 1998; Thornton and Wilkens, 1998).

The Decision Support System for Agro technology Transfer version 3.5 (DSSAT v 3.5) incorporates 16 crop growth simulation models for use in helping the decision makers (Hoogenboom *et al*., 1999), that includes CERES-model for maize (*Zea mays* L.), Wheat (*Triticum aestivum* L.), Rice (*Oryza sativa* L.), Sorghum (*Sorghum bicolor* (L) Moench), Millet (*Pennisetem typhoides* (Burm) Stap and Hubb), and Barley (*Hardeum vulgare* L.), CROPGRO-models for bean (*Phaseolus vulgaris* L.), Soybean (*Glycine max* (L) Merr.), Peanut (*Arachis hypogea* L.) Chickpea (*Cicer arientinum* L.), Tomato (*Lycopersicom lycopersicum* (L) Karsten) and pasture baniagrass (*Paspallum notatum* Fluegge), SUBSTOR-model for potato (*Solanum tuberosum* L.), OIL CROP-SUN-model for sunflower (*Helianthus annuus* L.), CANEGRO model for sugarcane (*Saccharum officinarum* L.), and CROPSIM – model for cassava.

The CERES-maize model was originally developed by an interdisciplinary team of scientists at the ARS-USDA grassland soil and water research laboratory in Temple, Texas, USA (Jones and Kiniry, 1986). This model was later adopted and modified by the IBSNAT (International Benchmark Sites Network for Agrotechnology Transfer) project (Ritchie *et al*., 1991). The CERES-maize, a physiologically based maize crop model included in the Decision Support System for Agrotechnology Transfrer (DSSAT), simulates the effect of weather, cultivar, management practices, soil water and nitrogen fertilizer on maize growth, development and yield (Tsuji *et al*., 1994), Hoogenboom *et al*., 1999).

### 2.6.1 Application of CERES model

The validated model could be used to simulate crop yield and other output variables reliably in different environments (Singh, 1989). The fundamental difficulty in all the models was that, most of them were based on collection of hypothesis and hence can not be validated inherently (Pease and Bull, 1992; Oreskes *et al*., 1994). Hence, validation is the essential process in modeling and ensures that models perform correctly when tested against observed data (Hunt and Boote, 1998; Boote, 1999). Dunchan (1986) used model to predict corn yield during the growing season using current weather data, and achieved satisfactory results.

The CERES – maize model has been extensively tested under tropical conditions of Hawaii, Indonesia and Phillippines (Singh, 1985) USA and Europe (Jones and Kiniry, 1986; Reicosky *et al.,* 1997; Bannuayen *et al*., 2003), Kenya (Keating *et al*., 1991) and India (Rajireddy, 1991; Shekh and Rao, 1996).

Kiniry and Jones (1986) evaluated CERES-maize model using various data sets of different locations covering varying situations and observed that the simulated value of maximum LAI, above ground dry biomass, grain number and grain yield had highly significant correlation with measured values.

The CERES-maize model was calibrated (Hodges *et al*., 1987) for the US corn belt by deriving varietal coefficients for each station based on minimal growth stages and yield data for the year 1982. The corn production was estimated for the years 1982 to 1985. The production estimates for 1982, 1983, 1984 and 1985 were 92, 97, 98 and 101 percent respectively of the official US government estimates. It was concluded that CERES-maize model could be applicable to large area yield estimation. Carberry (1991) calibrated the CERES-maize model and simulated rate of leaf tip appearance and leaf area expansion.

Jagtap *et al*. (1993) used CERES-maize model for validation, and simulated the grain yield, weight per grain, grains $m^{-2}$, LAI, stover weight and above ground biomass. Comparisons were made with field monitored data and the results were within 10 per cent of variation. Further, the excellent agreement between observed and simulated results with respect to above ground biomass, stem and leaf weight throughout the season showed that the partitioning rules in the models were robust and adequate.

Thornton *et al*. (1995b) validated the model for growth and development of maize crop using field experimental data of various sites of central Malawi between 1989 and 1992. Though, they observed slightly over estimated yield, summarized that the predicted yield had reasonable degree of accuracy over the range of conditions.

Shekh and Rao (1996) validated CERES-maize model using field experiments for two years at middle Gujarat agro-climatic region. The results obtained revealed that the prediction of silking date showed deviation which varied from –1 to +2 days with mean deviation of –2.3 days, physiological maturity ranged from –10 to +5 days with mean differences of –3.7 days. The prediction of grain, stover and biomass yield deviation ranged from –28.9 to +18.4, -8 to +16.2 and –15.6 to +17.5 per cent respectively.

Kiniry *et al.,* (1997) while demonstrating the capability of simulation of ALMANAC and CERES-maize for estimation of US corn belt yield, observed that both the models were adequate in predicting the yield for most of the corn growing areas and found superiority in prediction with CERES-maize model.

The CERES-sorghum model was validated at Rahuri for two sorghum cultivars namely Swati and M-35-1. The mean of observed number of days taken for panicle initiation, anthesis and physiological maturity were well matched with the predicted values (Varshneya *et al*., 1998). In a similar study, Raja (2001) reported that the CERES sorghum model well predicted the phenophases, yield parameters and yield of sorghum during normal year of rainfall. However, the model underpredicted the total biomass production during below normal year of rainfall.

Singh and Wilkens (1999) emphasized that the validated CERES maize model coupled with real time weather data facilitated and enhanced the model ability for yield forecast under limiting conditions and fine-tuned crop-management. At Pantanagar, Tripathi *et al.* (1999) validated CERES rice model. They concluded that the model results over-predicted as compared to observed experimental values.

Alves and Nortelift (2000) inferred that CERES maize model though did not account for all the factors that influence crop yield, but when calibrated and validated the model become a versatile tool for quantitative land evaluation.

Xie *et al*. (2001) evaluated the ability of a crop general model (ALMANAC) and crop specific model (CERES-maize) under dry growing season at several sites in Texas. They observed that the mean error of grain yield for CERES-maize and ALMANAC prediction was of 2 and 6.2 per cent for irrigated maize, -2.2 and 6.2 per cent for dryland maize respectively. Further, they also indicated that LAI and kernel weight were over sensitive to drought stress, the response of LAI and kernel weight to drought was valuable with CERES-maize. With similar study, Gijisman *et al*. (2002) reported that the DSSAT crop simulation models could be effectively used for simulating low input systems and conducting long term sustainability analysis by incorporating the CENTURY SOM residue model.

2.6.1.1 Genotype evaluation

The emergence of simulation models for large number of crops provided tools that may be useful in selection/evaluation of genotypes suitable to the specific environment. Crop simulation models have made a contribution in determining the responses of particular genotypes to the prevailing environmental characteristics (Field and Hunt. 1974).

Bailey and Boisvert (1989) used a crop model coupled with long-term weather data to evaluate the performance of range of groundnut cultivars at several locations in the semi-arid areas of India by incorporating economic concepts of risk efficiency. They found that the ranking of the cultivars differed from that obtained with the traditional approach (Finlay and Wilkinson, 1963) and depended crucially on the simulation of yield and therefore on the ability of the model to accurately simulate the crop's response to water deficits.

Muchow and Carberry (1993) used models for maize, sorghum and kenaf to analyse three crop improvement strategies such as modified phenology, improved yield potential and enhanced drought resistance.

Aggarwal *et al*. (1996; 1997) used ORYZA-1 model for investigating effects on grain yield of various traits such as developmental rates during juvenile and grain filling periods, leaf area growth, leaf N content, shoot/root ratio, leaf/stem ratio, and 1000 grain weight. They concluded that all parameters need to be increased simultaneously if there is to be any increase in yield, increasing one parameter alone has little effect. Further they also made the point that increase in nitrogen applications might be necessary to express the effect of genotype with higher yield potential as current N practices may be masking this potential.

Similar approaches have been used to assess the effects of different phenology in different varieties on grain yield of sorghum (Jordan *et al*., 1983; Muchow *et al*. 1991), Rice (Otoole and Jones, 1987) and Wheat (Stapper and Harris, 1989; Aggarwal, 1991). Hammer and Vanderlip (1989) simulated the impact of difference in phenology and radiation use efficiency on grain yield of old and new sorghum cultivars. Jagtap *et al*. (1999) used the CERES-maize model for evaluating the performance of different duration varieties. Further, they concluded that short duration varieties performed better than long duration varieties, and the risk of crop failure at three sites in Nigeria would be high if nitrogen is not applied.

#### 2.6.1.2 Planting dates

In most of the environments, the planting time of a crop has a major influence on its growth during the season and therefore on its final performance. This is particularly the case in variable environment or where there is a strong seasonal effect.

Omer *et al*.(1988) used a crop model and 11 years of climatic data to determine the optimum planting period in the dry land region of Western Sudan by generating probability distribution of water-stress indices resulting from different planting dates. The analysis showed a distinct optimum planting period June 20-July 10. And, planting in early July was the best period for better production. This simulated results agreed well with the general experience.

Carberry *et al*. (1989) tested the CERES-maize model for different sowing dates and water regimes at Katherine. They indicated that the original model over-estimated grain yield and total biomass at maturity. The reason for the poor predictions was attributed partly to the underprediction of silking date. Hence, they suggested some modifications in existing functions related to phenology, leaf growth and senescence, assimilates production and grain growth. These corrections were made in the revised model and further stated that the soil nitrogen supply and partitioning of rainfall into infiltration and run-off were the two probable sources of error in predicting maize yield in the semi-arid tropics.

Liu *et al*. (1989) used the CERES-maize model to simulate growth and grain yield of maize hybrid, DINA –10 for 5 years (1983 to 1987), They reported that the simulated yield was 98.3, 107.1, 103.6, 90.2 and 91.3 per cent of the measured yield for 1983, 1984, 1985, 1986 and 1987 seasons respectively. Further, difference of 9 days and 13 days of silking period was noticed during 1984 and 1986 respectively and it was attributed to lower temperature that occurred in the month of November and December during 1984 and 1986 respectively.

Wu *et al*. (1989) used CERES-maize model to simulate the maize yield in the North China plain. They reported that the model overestimated yield in wet years and underestimated yield in dry years. Under irrigated conditions the model yield simulations were improved. Further, they reported that when the model was modified to account for the effect of excess water through a crop moisture index, model yield improved further.

Rajireddy (1991) used the CERES-maize model to study the effect of planting dates and irrigation scheduling on growth and yield of *rabi* maize in Gujarat. He reported that the model predicted silking and physiological maturity dates very well, and grain yield data generally well matched with observed data.

The CERES-maize model was calibrated by Singh *et al*. (1993) and Thornton *et al*. (1995b) for local field conditions of Malawi, and determined the optimum planting windows and planting density for a number of varieties. Aggarwal and Kalra (1994) used the WTGRWOS model and showed that a delay in planting date decreased wheat yield, in part by subjecting the crop to warmer temperature during grain filling and stated that these results were confirmed with the experimental data for New Delhi presented by Phadnawis and Saini (1992).

Otegui *et al*. (1996) used the CERES-maize and other correlative models to know the effect of sowing dates on potential yield of maize hybrids in temperate region. The results indicated that CERES-maize accurately predicted development stage, however, the grain yield prediction was less reliable. Further, they stated that long cycle cultivars out yielded the short cycle hybrid.

Saseendran *et al*. (1998) used CERES-rice to determine the optimum transplanting date for rice in Kerala, the results obtained were on-par with observed data. Hundal and Kaur. (1999) used CERES-rice model to evaluate the age of seedling at transplanting, number of seedlings per hill, transplanting date and plant density for rice growing in Punjab (India). The results showed that the optimum date of transplanting for rice was June-15$^{th}$, but earlier transplanted (June-1$^{st}$) rice may perform better if seedling age reduced from 40 to 30 days. Increasing plant population increased rice yield.

Field experiments were conducted to validate CERES-maize model under varied times of sowing for farm decision-making. The results of the study indicated that CERES-maize predicted the date of tasseling and grain yield satisfactorily. But the model poorly predicted the biomass yield and harvest index (Karthikeyan, 2002).

2.6.1.3 Irrigation scheduling

Irrigation scheduling is an area in which models have been used extensively as decision support systems for various crops (Hill *et al*., 1983; Kundu *et al*., 1982; Raju *et al* 1983). The specific model application includes Corn (Stegman and Heerman, 1990; Stockle and James, 1989); Potato (Trooien and Heerman, 1988; Singh *et al*. 1989) and Soybean (Fortson *et al*., 1987).

Cabelguenne (1996) claims that there are at least 140 models based on the use of Doorenbos and Kassam (1979) water production functions. However, he points out that such models are unable to forecast correctly the effect of water constraints on the growth of the plant since they take no account of dynamic processes. Mechanistic agronomic models such as CERES-maize (Jones and Kiniry, 1986), EPIC (Williams *et al*., 1984) and CROPSYST (Stockle *et al*., 1994) are able to simulate the effect of water depletion during the growth cycle. Therefore, they can be effective tools for forecasting the water content of the soil and the crop response to it (Cabelguenne, 1996).

McGlinchey *et al*. (1995) described a pilot irrigation scheduling project established on commercial scale. The Meteorological variables measured with an automatic weather stations (AWS) on daily basis were transmitted electronically to the experimental station every week, based on these data a model could estimate the soil water content on daily basis. Accordingly, report on current soil water status is generated and advised the irrigator on when to irrigate, based on this irrigations were scheduled.

In South Africa the PUTU model (De jager *et al*., 1983) has been used for irrigation scheduling of many crops. CROPWAT, a model for estimating crop water requirement was used by the FAO to develop irrigation guidelines at a more strategic scale (Penning de vries, 1990). The CROPWAT approaches have been used widely by consultants and others while designing new irrigation schemes or introducing new crops that require irrigation. Similar irrigation planning approaches have been used in India to prepare irrigation calendars for cabbage, onion, tomato, maize, green gram and mustard (Panigrahi and Behara, 1998).

Algozin *et al*. (1988) used the model to evaluate the effect of irrigation application strategies on the economic yield of corn. Wu *et al*. (1989) showed that when the effects of irrigation and excess water were taken into account, CERES-maize model could be applied to the North China plain for yield estimation under wide range of moisture condition.

Steele *et al*. (1994) used the CERES-maize model to estimate crop dry matter in relation to water use under sandy soil and found that irrigation scheduling based on CERES-maize model could result in significant reduction in irrigation amount without significant reduction in yield compared to the reference treatment. Further, Pang (1995) successfully applied the CERES-maize model to characterize the Minnesota outwash soils to $NO_3$ leaching for different N and irrigation management scenarios. Plauborg and Heidmann (1996) used PC-based DSS (MARKVAND) – model for efficient forms of irrigation to provide daily information on the timing, amount and economic net return of irrigation for a wide group of agricultural crops in Denmark.

The crop yield and irrigation requirements were predicted through CERES-maize model and compared with other methods of irrigation scheduling, namely water balance technique referred as reference method (40 per cent depletion) and crop water stress index. The four year average results on crop yield and water saving showed that considerable amount of water could be saved with other methods including CERES-maize scheduling as compared to reference method without sacrificing the yield (Steele *et.al*., 1997).

The CERES-maize (v 2.1) model was evaluated by Pang *et al*. (1997a) and established quantitative relationship between N and irrigation amount on crop yield and $NO_3$ leaching under semi-arid condition for 3 years. In this study three irrigation amounts (20, 60 and 120 cm) and four N rates (0, 90, 180 and 360 kg $ha^{-1}$) was studied, the results indicated that the CERES-maize model could be applied with confidence to study the effects of N and irrigation management on corn yield and N-uptake. Further Pang *et al*. (1997b) established the relation between N rates and $NO_3$ leaching by using CERES-maize simulation values.

The IRRICANE model, now called CANESIM and partly derived from the CANEGRO-model of DSSAT was used for irrigation scheduling (Singels *et al*., 1998) as a tool to assist in the agronomic management of sugarcane (Singels *et al*., 2000). Matthews *et al.,* (2002) while describing the crop/soil simulation model application for irrigation scheduling reported that the mechanistic models are effective tools in developing and developed countries, in former such systems are applied in a commercial context whereas in the later they have been used by individual farmers.

2.6.1.4 Plant density

The density of planting is another agro-techniques that have been investigated with crop models. The early work on determining optimum planting density used static models which related plant density to overall yield and to its components, such as yield $plant^{-1}$ (Stickler and Wearden, 1965). Crop models have been used to develop and confirm these relationships for particular environments. Keating *et al*. (1988) used the CERES-maize model to examine the effects of plant density on maize yield as influenced by water and nitrogen limitation in Kenya, found that the density for maximum yield increased as N supply increased. Singh *et al*. (1993) carried out a similar analysis in Malawi.

Wade (1991) used the SORKAM-sorghum model to analyse risk associated with different planting densities (low, standard and high) at three contrasting sites in Australia. At one site it was always better to opt for high density and narrow rows, whereas at other two sites the standard practice appeared to be the best compromise. Over 30 years, the high planting density gave higher yield in 5 years, but crop failure in 14 years as compared to the standard. Low plant density at these sites gave only four crops failures but yields were lower in good years. The model was also used to investigate the effect of variation in crop stand uniformity. It was predicted that a poor distribution of plants gave 11 per cent less yield than the same plant density with uniform distribution. Whereas, variation in both plant density with plant distribution gave 25 per cent less yield. Finally it was suggested that this kind of analysis with simulation models might have helped in making decisions on whether it is necessary to replant a poorly established plant stand or not. Lansigan *et al*. (1997) used the ORYZA model to generate probability distribution of rainfed lowland rice yield for different planting densities and seedling age at transplanting.

Due to their dynamic nature, the crop models offer a way of exploring variations in their relationship between environments or from year to year, and therefore models could be used to quantify the risk faced by the farmer of choosing a particular planting density in a particular environment. Quantification of this risk is particularly important in variable environments. A low planting density may mean at least some yield in a poor year even though yield may be sacrificed in a good year. A high planting density on the other hand may mean that maximum yield obtained in a good year but no yield at all in a poor year. The most appropriate strategy for planting density, therefore depends on both the specific environment and the farmer's attitude to risk. A risk averse farmer should use a low density strategy whereas, a more risk tolerant farmer may opt for a higher density and therefore maximize his income over the long term, despite total crop failure in some years (Matthews *et al*., 2002).

2.6.1.5 Nitrogen management

In many parts of the world, specially in tropical countries, fertilizer is a relatively expensive commodity. In such countries, the availability of nitrogen to the crop and hence the efficiency of use of N fertilizers is often highly variable, much of which is caused by variation in the prevailing climate and soil conditions. The soil moisture can affect the uptake of N by the crop as well as N mineralization. For example, low soil moisture or drought can restrict the uptake of N by the crop as well as reduce rates of N mineralization, on the other hand, heavy irrigation or too high a rainfall can result in losses of N from the soil by leaching and denitrification. Therefore, it is difficult to define a single fertilizer strategy which is optimum in all the conditions/seasons. As a result, there is often mismatch between supply and demand of N, thereby reducing yield or washing fertilizer. Field experiments conducted in variable environments may give misleading results as the years in which they are conducted may not represent the long-term average. In such cases, crop models provide a way of assessing particular options, thereby complementing the experimental results (Matthews *et al*., 2002).

Singh *et al*. (1985) used CERES-maize model to simulate the response of N applications and found that simulated yield responses to N application generally were within two standard error of the mean. The CERES-maize model realistically predicted grain yield in response to increasing N rates and mineral N present in the soil profile at the start of simulation (Jones and Kiniry, 1986).

Keating *et al*. (1991) used modified version of the CERES-maize model (CM-KEN) to investigate the factor influencing response to N in Machakos, Kenya, looking at variations in organic matter, mineral N and soil water at planting, runoff characteristics, plant density, and timing of N applications. In all the cases, the response to N varied according to the amount and pattern of rainfall in the season. Taking into account year-to-year variability, they were able to use the CERES-maize model to plan a hypothetical development pathway involving the application of more N and increasing the plant density.

Thornton and Hoogenboom (1994) showed how an increase in applied N might effect both crop yield and nitrate leaching potential of shallow sand and deep loam by running the maize model. The N fertilizer rate was from 25 to 300 kg $ha^{-1}$. Data showed yield response in both the soils, however leaching was much greater under shallow sand than deep loam. The critical value of nitrogen $ha^{-1}$ for nitrate leaching would mean 100 kg $ha^{-1}$ but not more than 150 kg $ha^{-1}$ under shallow sand. In deep loam, near maximum yield could be obtained with application of less N with minimum losses due to leaching.

While estimating the economic value for optimum application schedule of N fertilizer ranged from 49 to 240 kg N $ha^{-1}$ through simulation studies using CERES- maize model for different years between 1978 and 1987, Thornton and Macrobert (1994) concluded that the optimumN application schedule in any season was found to be highly dependent on weather. Further, the authors suggested based on simulated results that considering practicability, the reasonable number of fertilizer application could be every 10 days interval from planting and fertilizer applied 90 days after planting had no positive effect on economic returns.

Bowen and Baethgen (1998) used the CERES-model to explore systematically some of the factors influencing N dynamics in soils, taking into account crop N demand as effected by days to maturity and soil N support as effected by the amount of soil organic matter, rainfall, and initial soil mineral N. As might be expected, longer maturing genotypes took up more N than earlier maturing genotypes. Both high soil organic matter levels and high initial soil mineral N levels resulted in higher crop N uptake. Interestingly, there was a maximum crop N uptake in relation to annual rainfall at first, N uptake increased as rainfall increased the growth of the crops, but at rainfall above 500 mm crop uptake declined as leaching losses became more significant. It was shown how such results could be used to evaluate different soils trade-offs between potential benefits of applying N fertilizer in terms of yield and environmental cost in terms of nitrate leached. Alocilja and Ritchie (1993) who used the SIMOPT2: maize model based on CERES-maize and made similar analysis and investigated the trade-off between maximizing profit and minimizing nitrate leaching.

Singh *et al*. (1993) used the CERES-maize model to determine N response curves for two different maize cultivars and two different sites in Malawi over number of years. Based on these data they calculated the economically optimum rate of N fertilizer application. Thornton *et al*. (1995b) took the analysis one step further by linking it to a GIS with spatial database of soils and weather to analyse the influence of N management on crop yield and leaching potential at the regional level. Thornton *et al*. (1995a) carried out a seasonal analysis in Malawi and classified the seasons over a number of years according to their start (i.e. early, normal, late) and calculated maize yields for each group. Results showed that yield decreased with the later the season started. The optimal rate of fertilizer application was 90 kg N $ha^{-1}$ for early starting seasons and declining to only 30 kg N $ha^{-1}$ for late starting seasons.

2.6.1.7 Optimizing multiple crop management options

Models have been used to provide information on more than one aspects of crop management. Wafula (1995) used locally adopted version of CERES-maize for a variety of applications in the Machakos, Kenya. And, used 32 years weather data for model simulations and established the probabilities of outcome for combination of different management variables, including optimum sowing dates, the model output supported the message that was already being given by extension workers (early cropping reduces the risk of crop failure) but that, until then, had no quantitative support. The model also demonstrated that the suggested practice of high density cropping could have negative effect where there were N limitations (Keating *et al*., 1993) and thus highlighted the need for moderate fertilizer N application. CERES-maize model has been validated in Malawi using field experiments as reported by Singh *et al*. (1993) and obtained satisfactory performance for the location tested. With simulation experiments useful informations on planting dates, plant population, fertilizer regimes and variety selection were obtained.

Thornton *et al*. (1995b) validated CERES-maize model using data sets obtained from field experiments run at various sites in the mid altitude maize zone of central Malawi. The model was used to provide information concerning management options such as timing and quantity of nitrogen fertilizer application, varietal selection and to quantify weather related risks of maize production. They concluded that CERES-maize predicted yield reasonably accurate over the range of conditions that pertained to Central Malawi. Further, having established that the model was working reasonably well for conditions in Malawi, optimum planting dates, optimum plant densities and nitrogen applications were described. Simulated results confirmed that the recommended planting densities of 3.7 plants $m^{-2}$ for local varieties and 4.4 plants $m^{-2}$ for short statured hybrids were well suited for current management systems. Simulated nitrogen fertilizer management indicated that optimum nitrogen application rate based on grain yield for both local and hybrid varieties varied from 80 kg N $ha^{-1}$ at 3.7 plants $m^{-2}$ to 150 kg N $ha^{-1}$ at 6.4 plants $m^{-2}$. Split application of nitrogen fertilizer found to be beneficial in the sandy soils of the region. They also indicated economically optimum dose of N fertilizer application which ranged from 60 to 100 kg N $ha^{-1}$.

The CERES model was evaluated by Pang *et al*. (1997a and 1997b) using experimental data on irrigation and fertilizer management trails on corn conducted at Davis compared with the measured yield and total N uptake under irrigated conditions. Further they concluded that the CERES maize model could be applied with confidence to study the effect of N and irrigation management on corn yield and N uptake under irrigated semiarid conditions. They also opined that though $NO_3$ leaching measured were not made available to compare with the simulated $NO_3$ leaching, one would expect the simulated $NO_3$ leaching to be reasonable since the model predicted N uptake and yield quite well. Pang *et al*. (1997b) quantified the relationship between irrigation management and N management on $NO_3$ leaching. The yield and N leaching were simulated using CERES-maize (v 2.10) model for various combination of irrigation amount and uniformity, and N amount and timing of N applications. Simulated grain yield increased, reached a plateau, and decreased with increase in applied water above which yield decreased was higher in the higher N application rate and the later split N application. The simulated amount of N leached was consistent with yield results. The higher water application that lead to reduced yield was associated with higher N leaching for a given N application and they also concluded that under non uniform irrigation it was impossible to manage either water or N application.

# III. MATERIAL AND METHODS

Field experiments were conducted at Agriculture College Farm, University of Agricultural Sciences, Dharwad during 1998-99 and 1999-2000 winter season under irrigated condition. The details of material used and experimental techniques adopted during the course of investigation are elaborated in this chapter.

## 3.1 EXPERIMENTAL SITE

The Agriculture College Farm, University of Agricultural Sciences, Dharwad is located at $15^0$ 26'N latitude, $75^0$ 07'E longitude and at an altitude of 678 m above sea level (MSL).

## 3.2 CLIMATIC CONDITION AND SEASON

The Agriculture College Farm, Dharwad is situated in the Northern Transitional Zone (Zone –7) Karnataka and has the climate of semi-arid tropics. The meteorological data of experimental years and mean of 48 years are presented in Appendix 1 and depicted in Fig. 1 and 2. The average total annual rainfall for the station is 798.24 mm, of which 60 percent (475.49 mm), 22 percent (177.85 mm) and 18 percent (144.90 mm) are received during rainy (June-September), post rainy (October-January) and summer (February-May) seasons respectively. The rainfall is fairly well distributed from April to November with two peaks, one in July (156 mm) and another in October (136.62 mm). The total annual rainfall received during 1998 and 1999 was 93 percent (742.2 mm) and 53 percent 422.8 mm) of the annual average. During the cropping season namely 1998-99 and 1999-2000 *rabi* (October to March), the rainfall received was 74.5 (138.3 mm) and 86.7 percent (161 mm) of the seasonal average (185.62 mm), respectively.

The annual average maximum and minimum air temperature is $31.2^0$C and $18.5^0$C respectively. April ($37^0$C) and May ($36.7^0$C) are the hottest months, whereas December ($13.4^0$C) and January ($14.11^0$C) are the coolest months. During the two experimental seasons the maximum air temperature ranged between $28.6^0$C and $36.2^0$C and minimum air temperature between $15^0$C and $21^0$C, which were very ideal for maize crop.

The average monthly relative humidity (%) was fluctuating between 50 and 88 percent. The monthly mean value during cropping seasons fluctuated between 63 and 84 percent during 1998-99 and 79 and 45 percent during 1999-2000. Similarly variations with respect to wind speed were observed and it was 0.5 to 19 km hour$^{-1}$. During the cropping period, relatively lesser wind speed of 5 to 7.7 hour$^{-1}$ was recorded during *rabi* as compared to either *kharif* (9 to 19.6 km hour$^{-1}$) or summer (7.5 to 13.1 km hour$^{-1}$).

The daily evaporation (mm day$^{-1}$) varied between 4.2 and 5.3 mm in December and January; 8.4 and 12.3 mm during April and May respectively. The total annual evaporation was 1059.5 mm and 1584.57 mm during 1998 and 1999 respectively. The monthly mean varied between 1.3 and 6.9 mm during 1998-99 and 2.01 and 8.01 mm during 1999-2000 cropping period.

The daily solar radiation ranged from 9 to 24 MJ m$^{-2}$ day$^{-1}$ and 8.10 to 24.8 MJ m$^{-2}$ day$^{-1}$, while the monthly mean solar radiation varied from, 16.1 to 22.9 m$^{-2}$ day$^{-1}$, and 16.6 to 23.6 MJ m$^{-2}$ day$^{-1}$ during 1998-99 and 1999-2000 cropping seasons respectively. In general, all the weather parameters recorded during *rabi* cropping seasons of both the years are better suited to the maize crop except rainfall. The rainfall distribution pattern very-well suited to early *kharif* and *kharif* crop, however irrigation is much indispensable for the crop grown during post-rainy/*rabi* and/or summer season crop.

## 3.3 DESCRIPTION OF THE SOIL

The study was conducted in vertisol, which are deep black soils generally called black cotton soils, representing 80 percent of the irrigated command area in the Northern Karnataka. The texture is clay loam with basic reaction (pH 7.9) and medium nitrogen, high in phosphorus and potash content. Composite samples were drawn to fulfill the minimum data

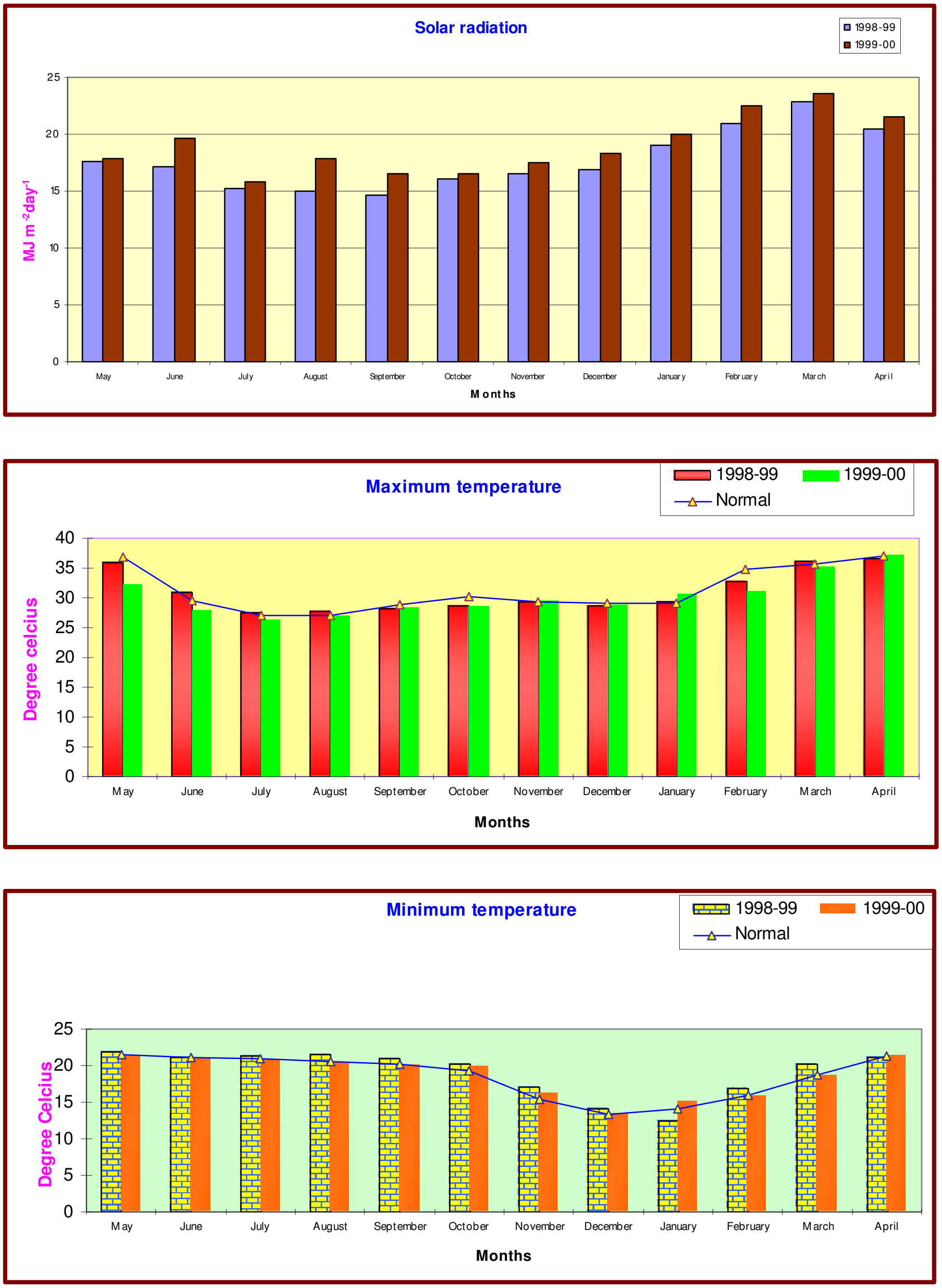
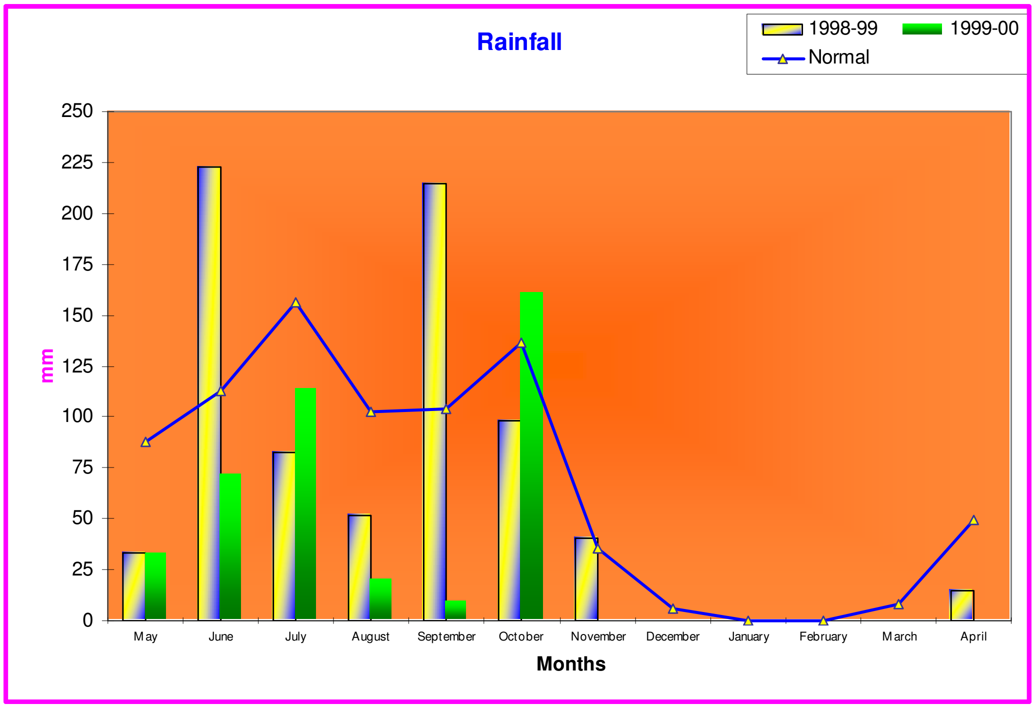



Fig 1. Solar radiation, maximum and minimum temperature at College of Agriculture, Dharwad



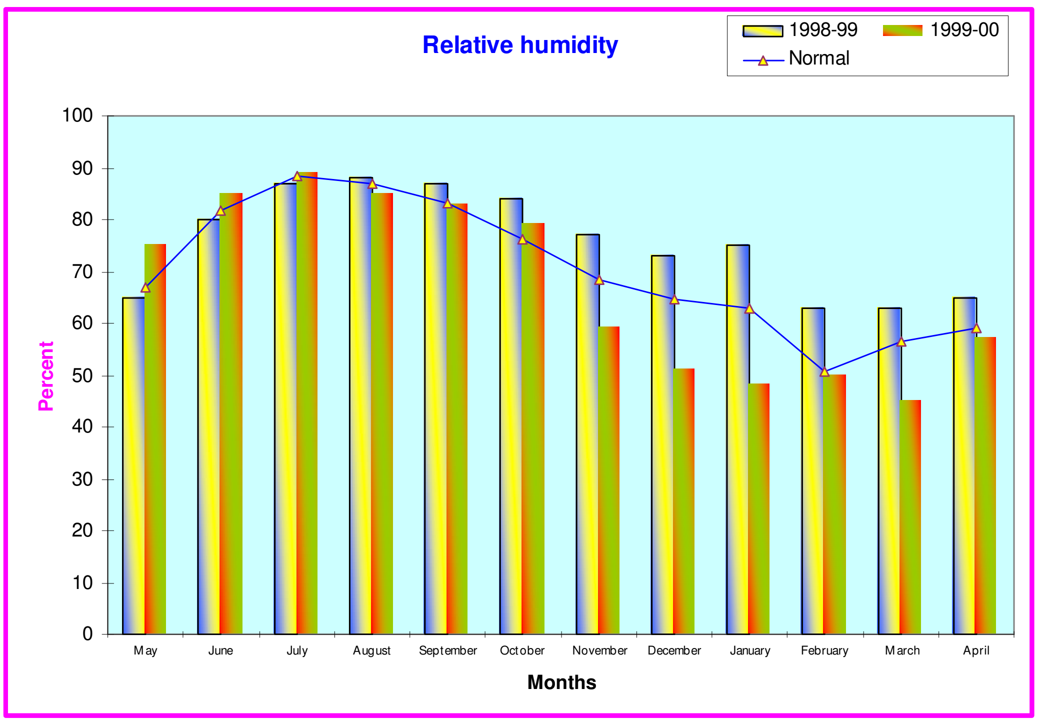




**Fig 2. Rainfall and Relative humidity at College of Agriculture, Dharwad**

set of soil input file. The samples were analyzed for physical and chemical properties of the soil (Appendix 2).

## 3.4 PREVIOUS CROP IN THE EXPERIMENTAL AREA

The experimental site was kept fallow during *kharif* season, and in the succeeding *rabi* season the experimental crop was cultivated.

## 3.5 EXPERIMENTAL DETAILS

The details of the different maize experiments are given below.

### 3.5.1 Experiment No.1:

**Effect of planting dates on growth and yield of maize varieties during *rabi* under irrigated condition**

Season (s) : 1998-1999 *rabi*

1999-2000 *rabi*

**Treatments :** 4 X 5 = 20

There were twenty treatment combinations consisting of four planting dates and five varieties

**Main plots: Planting dates (Four)**

$D_1$ : October I fortnight ($10^{th}$ of October)

$D_2$ : October II fortnight ($25^{th}$ of October)

$D_3$ : November I fortnight ($10^{th}$ of November)

$D_4$ : November II fortnight ($25^{th}$ of November)

**Sub plots : Varieties (Five)**

$V_1$ : Deccan –103

$V_2$ : DMH-1

$V_3$ : DMH-2

$V_4$ : Prabha (G-57)

$V_5$ : Renuka (G-25)

**Design** : Split plot

**Replications** : Three

**Plot size** : Gross = 6.0 m X 5.4m = 32.40 Sq.m

Net = 3.6 m X 4.2 m = 15.12 Sq.m

Plan of layout depicted in Fig.3 and Plate

### 3.5.2 Experiment No.2

**Effect of irrigation scheduling, plant density and nitrogen levels on growth and yield of winter maize**

**Season (s) :** 1998 – 1999 *rabi*

1999 – 2000 *rabi*

**Treatments** : 3X 3 X 4 = 36

There were 36 treatment combinations including three irrigation scheduling three plant densities and four nitrogen levels.

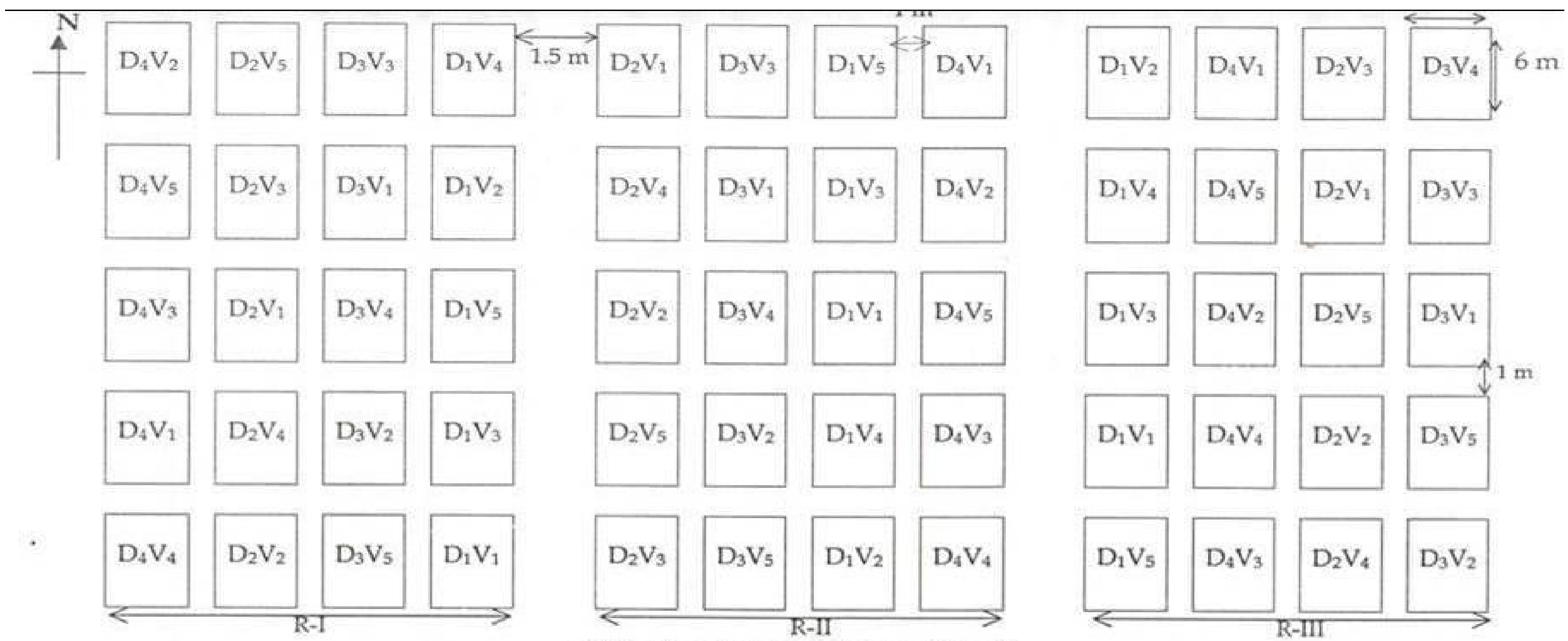



**Fig 3. Plan of layout of experiment-I**

**Legend**

**Planting dates**

$D_1$ : October I fortnight (10th of October)
$D_2$: October II fortnight (25th of October)
$D_3$ : November I fortnight (10th of November)
$D_4$ : November II fortnight (25th of November)

**Varieties**

$V_1$ : Deccan – 103
$V_2$ : DMH-1
$V_3$ : DMH-2
$V_4$ : Prabha (G-57)
$V_5$ : Renuka (G-25

**Fig. Plan of layout of experiment I**

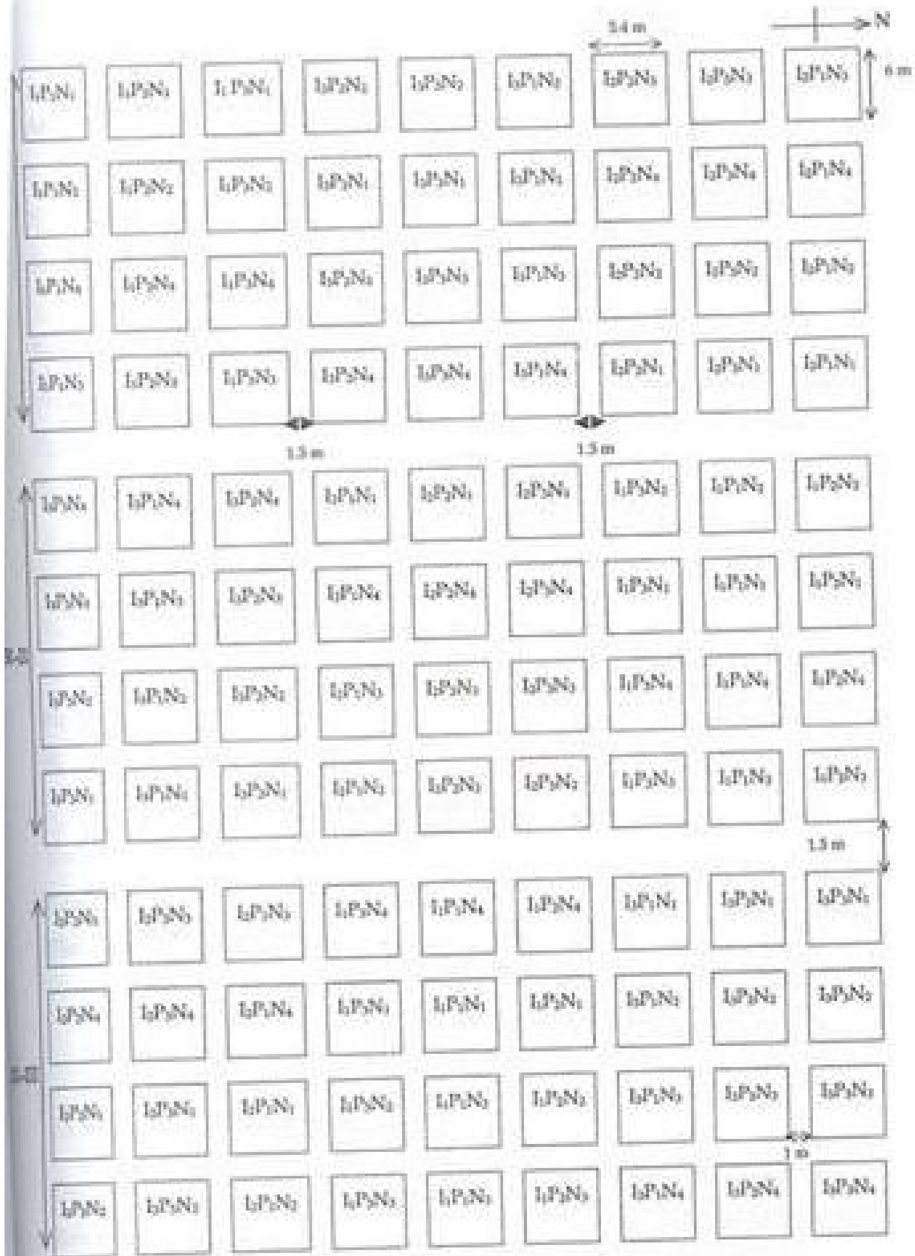



Fig 4. Plan of layout of experiment-II

Legend :

**Irrigation scheduling**
$I_1$ = 0.6 IW/CPE ratio
$I_2$ = 0.9 IW/CPE ratio
$I_3$ = 1.2 IW/CPE ratio

**Plant density**
$P_1$ = 55,555 plants ha$^{-1}$ (60×30cm)
$P_2$ = 83,333 plants ha$^{-1}$ (60×20cm)
$P_3$ = 1,11,111 plants ha$^{-1}$ (60×15cm)

**Nitrogen levels**
$N_1$ = 75 kg N ha$^{-1}$
$N_2$ = 150 kg N ha$^{-1}$
$N_3$ = 225 kg N ha$^{-1}$
$N_4$ = 300 kg N ha$^{-1}$

**Fig. 4 Plan of layout of experiment-II copy**

**Main plots:** Irrigation scheduling (3)

$I_1$ : 0.6 IW/CPE ratio

$I_2$ : 0.9 IW/CPE ratio

$I_3$ : 1.2 IW/CPE ratio

**Sub plots :** Plant density (3)

$P_1$ : 55555 plants ha$^{-1}$ (60 X 30 cm)

$P_2$ : 83333 plants ha$^{-1}$ (60 X 20 cm)

$P_3$ : 111111 plants ha$^{-1}$ (60 X 15 cm)

**Sub –sub plots** : Nitrogen levels (4)

$N_1$ : 75 kg ha$^{-1}$

$N_2$ : 150 kg ha$^{-1}$

$N_3$ : 225 kg ha$^{-1}$

$N_4$ : 300 kg ha$^{-1}$

**Design** : Split-split plot

**Replications** : Three

**Plot size** : Gross 6.0 m X 5.4 m = 32.40 Sq.m

Net : 3.6 m x 4.2 m = 15.12 Sq.m

Plan of layout is given in Fig.4 and plate 1.

## 3.6 MAIZE GENOTYPES:

**Deccan 103** : Full season high yielding maize hybrid, suitable for *Kharif* and *Rabi* seasons. It matures in 110-115 days, gives a grain yield of 48-50 q ha$^{-1}$ and stover yield of 6-7 t ha$^{-1}$.

**DMH-1** : Full season high yielding maize hybrid recommended for both *Kharif* and *Rabi* seasons. It matures in 105-115 days, gives a grain yield of 50-52 q ha$^{-1}$ and fodder yield of 7 to 7.5 t ha$^{-1}$.

**DMH-2** : Full season single crobs high yielding maize hybrid, suitable for both *Kharif* and *Rabi* Seasons. It matures in 115-120 days and gives 55-56 q ha$^{-1}$ grain and 8 to 10 t ha$^{-1}$ fodder yield.

**Prabha (G-57) :** Full Season high yielding composite maize variety recommended for cultivation both for *Kharif* and *Rabi* seasons. It matures in 115-120 days, record a grain yield of 48-50 q ha$^{-1}$ and 6-7 t ha$^{-1}$ fodder.

**Renuka (G-25) :** Short duration composite maize variety, recommended for cultivation in *Kharif*/*Rabi* seasons. Matures in 85-90 days duration and gives a grain yield of 40-45 q ha$^{-1}$ and 5 to 6 t ha$^{-1}$ fodder yield.

## 3.7 CULTURAL OPERATIONS

### 3.7.1 Land preparation

Prior to sowing of the experimental crop, the land was tilled with tractor driven cultivator twice, followed by two harrowings to bring the soil to fine tilth. During layout, small bunds were provided all around each plot, and between irrigation channel and replications. The land within each plot was leveled in order to maintain uniform irrigation water application.

### 3.7.2 Seed treatment

As a precautionary measure and to maintain required population, the seeds were treated with Ridomil @ 3 g kg$^{-1}$ of seeds at the time of sowing to protect plants from Downey mildew disease.

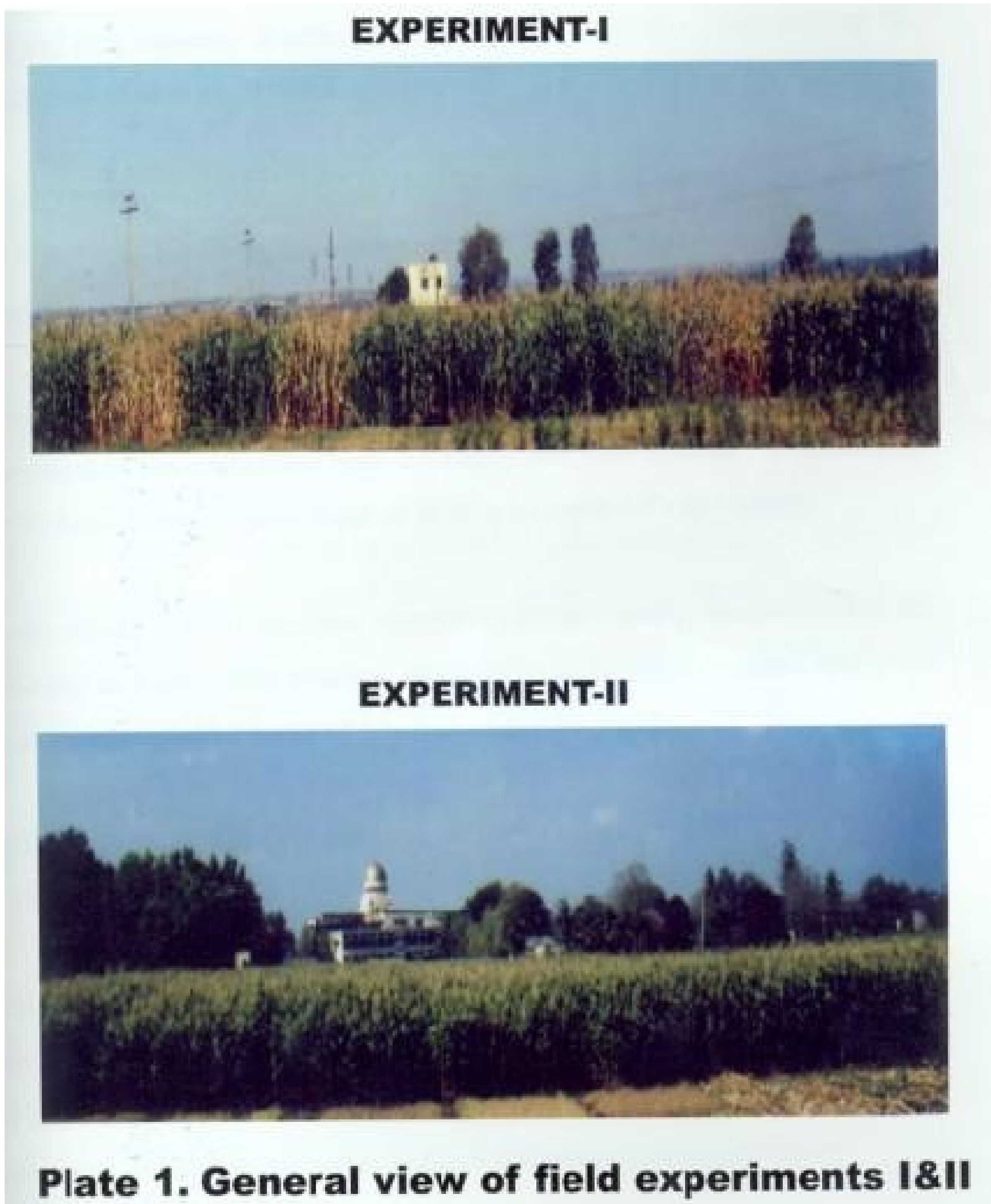



**Plate 1. General view of field experiments I & II**

### 3.7.3 Fertilizer application

Nitrogen was applied as per the treatments (wherever it was required) in the form of prilled urea (46% N) in three equal splits (1/3 each at basal, at 30 and 50 days after sowing). The full dose of phosphorus @ 75 kg $ha^{-1}$ and potassium @ 37.5 kg $ha^{-1}$ in the form of super phosphate and muriate of potash respectively, were applied at the time of sowing. The fertilizers at sowing were applied in 60 cm apart rows, 15 cm deep and 5 cm away from seed rows. The top dressing of nitrogen fertilizer during the crop growth periods was band placed at 10 cm deep and 10 cm away from seedlings. The required zinc sulphate @ 20 kg $ha^{-1}$ was applied before sowing to all the treatements.

### 3.7.4 Sowing

The furrows were opened at 60 cm apart about 5 cm away from the fertilizer band and two to three seeds per hill were dibbled in furrows to a depth of 4 cm. After establishment of crop at 10 days of emergence, thinning was done by leaving one seedling per spot to maintain required plant density as per treatment in experiments-II, however in experiment-I 30 cm intra-planting spacing was maintained.

### 3.7.5 Irrigation

Furrow method of irrigations was followed. Irrigations were given as per the treatments in experiment-II and at 10-15 days interval in experiments-I.

In IW:CPE approach, cumulative pan evaporation values from standard USWB class 'A' pan evaporimeter were used for scheduling of irrigation (Appendix 3). A common depth of irrigation was maintained at 6 cm uniformly. In all the treatments, measured amount of irrigation water drawn from the tubewell was applied to each plot by measuring the discharge collected in known volume of bucket in unit time (Pruitt, 1960; Jenson *et al.*, 1961).

### 3.7.6 Weed control and plant protection measures

The experimental plots were kept free from weeds throughout the crop growth periods by pre-emergent application of Atrataf and hand weeding. Adequate plant protection measures were adopted to control the major insect pests and diseases. At the time of sowing Furadon was applied in the rows to control cut worms during crop growth periods the crop was sprayed with monocrotophos Endosulfan 35% EC (2ml $l^{-1}$ of water) and Dithane M-45 (2.25 g $l^{-1}$ of water ) at 20 and 40 days after sowing. And, malathion (5%) @ 25 kg $ha^{-1}$ was dusted during silk emergence stage to control cob borer.

### 3.7.7 Harvesting and threshing

Harvesting was done after complete maturity of the crop. The cobs were harvested from net plot area, air dried and kernels were separated and cleaned, then yield per plot was recorded at 13 per cent moisture. Similarly, stalks were cut just above the ground level and were left in the field for drying. After complete sun drying the weight of the stalks per plot was recorded.

## 3.8 COLLECTION OF EXPERIMENTAL DATA

### 3.8.1Observations

#### 3.8.1.1.Days to 50 per cent flowering

Ten tagged plants were used for the determination of days to 50 per cent flowering, when flowering was noticed on 50 percent of the plant. Similarly, silking was recorded when silks were extruded and remained green/ red green on 50 percent of plants.

#### 3.8.1.2 Physiological maturity

Physiological maturity was determined by regularly sampling two cobs per plot to assess the presence of black layer at the base of the grain, indicating that no further accumulation of grain mass was possible (Daynard and Duncan, 1969). Grains were removed from the base, middle and distal end of each cob. Days to physiological maturity was recorded when atleast 75 percent of the grains in each cob had black layer.

### 3.8.2Growth components

The growth parameters were recorded periodically from each plot at 30 DAS, anthesis and physiological maturity in Expt. No.1, and at 30, 60, 90, 120 DAS or/and physiological maturity in Expt. No.2.

3.8.2.1Plant height(cm)

Ten tagged plants were used for recording plant height, and was measured from base of the plant to the base of the fully opened leaf.

3.8.2.2. Number of leaves plant$^{-1}$

Fully opened leaves from ten tagged plants were counted, averaged and expressed as number of leaves plant$^{-1}$.

### 3.8.2.3.Leaf area index (LAI)

Leaf area index is defined as leaf area of assimilatory surface per unit land area (Sestak *et al*., 1971). The Leaf area index was measured by LI-COR:LAI-2000 plant canopy analyzer (Welles and Norman, 1990).

3.8.2.4.Dry matter accumulation

Five plants from each plot were collected randomly by cutting or then from ground level at different growth stages. The samples were sun-dried and then oven dried at 70$^0$C temperature for 24 to 48 hours till the constant weight was obtained and averaged to get data in g plant$^{-1}$.

### 3.8.3.Yield components

3.8.3.1. Grain weight (g grain$^{-1}$)

Grain weight was taken from dry grain sub samples, averaged, and expressed as dry weight (g grain$^{-1}$).

3.8.3.2.Grain number ear$^{-1}$

Grains number was calculated from ear sub samples, averaged and expressed as grain number ear$^{-1}$.

3.8.3. 3. Number of grains m$^{-2}$

Grain number was taken from ear sub samples, and averaged and multiplied by number of ears m$^{-2}$, and expressed as grain number m$^{-2}$.

3.8.3.4 Grain yield

The kernels from the air-dried cobs from each net plot were separated, cleaned and dried to obtain at least 13 per cent moisture. Weight of grains was recorded and expressed as grain yield in kg ha$^{-1}$.

3.8.3.5. Stover yield

The yield of stover from each plot was recorded when it was completely sun dried and expressed as stover yield in kg ha$^{-1}$.

3.8.3.6 Total biomass yield

The above ground biomass (seed + stover) from each net plot was recorded and expressed in kg ha$^{-1}$.

3.8.3.7 Harvest index

Harvest index is defined as the ratio of economic yield to the biological yield. It was calculated by using the formula given by Donald (1962).

$$\text{Harvest index} = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Biological (Grain + Stover) yield (kg ha}^{-1})}$$

3.9.1 Chemical analysis

The plants sampled at physiological maturity were used for chemical analysis. The plant samples were powdered in a "Willey mill" to pass through 40 mesh sieve. The required plant samples (0.5 g) were used for nitrogen estimation through micro-kjeldahal method (Jackson, 1973). The nitrogen content was expressed as percentage on oven dry basis and nitrogen uptake kg ha$^{-1}$.

3.9.2. Water management studies

3.9.2.1. Water use (mm)

Water used was calculated as detailed below.

Water use (mm) = Soil moisture depletion (mm) + effective rainfall (mm)

3.9.2.2. Water use efficiency (WUE)

The weight of economic yield per unit of water used is referred to as water use efficiency and was calculated by using the formula given by Viets (1962).

$$\text{WUE (kg ha}^{-1}\text{ mm}^{-1}) = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Water used ( ha mm}^{-1})}$$

### 3.9.3. Economic Analysis

The cost of production was worked out by taking into account of expenditure incurred to meet the requirements of various inputs such as seeds, FYM, fertilizers, weedicides, pesticides, irrigation water and labours, bullock pairs, farm machineries required to carry out various cultural operations from pre-sowing stage to harvest and post harvest operations. The value of the main and by product was calculated using the prices which existed during corresponding cropping periods (Appendix 4). The cost of production incurred and gross income realised were utilized to calculate net return and benefit cost ratio.

## 3.10 SIMULATION STUDIES OF DSSAT v 3.5 CERES-MAIZE MODEL

To know the role of simulation model in agronomic research, the Decision Support System for Agro-technology Transfer (DSSAT) v 3.5 CERES-maize model was used, which is a DOS-based modeling and application system. All its functions are fully supported in Windows 95, Windows 98, Windows NT and OS/2 operating systems (Tsuji *et al.*, 1994). This model was used to simulate the growth, development and yield of maize as influenced by genotypes, planting dates, nitrogen dose, plant density and irrigation scheduling for the experiments conducted during the cropping seasons of 1998-99 and 1999-2000.

### 3.10.1. INPUT requirements to run CERES – maize model

For simulation of CERES maize model, minimum data sets (MDS) on crop management, macro and micro-environmental parameters associated with weather, soil and crop are required as input. Input data files of CERES-maize model are as per IBSNAT standard input/output formats and file structure described in DSSAT v 3 (Hoogenboom *et al.,* 1999).

### 3.10.2 Weather information

Daily weather data required are total solar radiation (MJ m$^{-2}$ day$^{-1}$) minimum and maximum air temperature ($^{0}$C) and rainfall (mm). These daily weather data including site specific information, other optional weather variables were collected and used for creating weather file (UADW. WTH) and running CERES maize model.

### 3.10.3 Soil information

The soil samples are collected from opened-up soil profile and described layer wise soil physical and chemical characteristics. The same data are used for creating soil file (UADW.SOL) for running CERES-maize model.

### 3.10.4 Genetic coefficients

To simulate a crop variety the CERES-maize model requires six genetic constants, namely,

**P-1:** Thermal time from seedling emergence to the end of the juvenile phase (expressed in growing degree days above a base temperature of $8^0$C) during which plant is not responsive to changes in photoperiod.

**P-2 :** Extent to which development (expressed as days) is delayed for each hour increase in photoperiod at which development proceeds at a maximum rate (which is considered to be 12.5 hours).

**P-5 :** Thermal time from silking to physiological maturity (expressed in degree days above a base temperature of $8^0$C).

**G-2** : Maximum possible number of kernels plant$^{-1}$.

**G-3** : Kernel filling rate during the linear grain filling stage under optimum condition (mg day$^{-1}$).

**PHINT** : Phylochron interval; the interval in thermal time (degree days) between successive leaf tip appearances.

The genetic constants for the cultivar used in the present simulation studies were estimated using silking and maturity dates (Ritchie *et al*., 1990), grain yield (dry), biomass at maturity, grain number m$^{-2}$, grain number ear$^{-1}$ and grain weight. The genotype coefficient calculator (GenCalc) version 3 was used to determine the genotype coefficient (Hunt, 1988; Hunt *et al*., 1993; Hunt and Pararaj singham, 1993). The GenCalc v-3 was run repeatedly as per the procedure (Tsuji *et al*., 1994) to obtain the calculated value equals to the observed value. Similarly, same process was used for obtaining genetic coefficients of other genotypes. The same values of genetic constants are used for simulation of 1998-99 and 1999-2000 growing seasons. No other adjustments were made in the model.

## 3.11 EXPERIMENTAL DETAILS

Experimental input files for each experiment was created as per the defined treatments and treatment combinations. The experimental details which are already prescribed in earlier section of this chapter (3.5) were used as input to experimental file.

### 3.11.2 Simulation studies

After the weather, soil, genotype and crop management input files were created for a specified simulation experiment, the CERES -maize model was run and output files were generated. These simulation results were compared with observed data.

## 3.12 STATISTICAL ANALYSIS AND INTERPRETATION OF RESULTS

Standard procedures were adopted as outlined by Gomez and Gomez (1984). The level of significance used in ‘F’ and ‘t’ test was P=0.05, critical difference (CD) values were calculated at 5 percent probability level wherever the ‘F’ test found significant.

The CERES-maize simulated values were compared with measured values and were statistically analysed. The root mean square error (RMSE) was used to estimate the variation between simulated and measured values and expressed in the same unit as the data (Loague and Green, 1991; Xevi *et al*., 1996). This parameter is defined by

$$\mathrm{RMSE} = \left( \sum_{i=1}^{n} (Si - Mi)^2/n \right)^{1/2}$$

Where $M_i$ and $S_i$ are the measured and simulated values, respectively for the $i^{th}$ data point of n observations. RMSE tests the accuracy of the model, which is defined as the extent to which simulated values approach a corresponding set of measured values (Loague and Green, 1991). A smaller RMSE indicated less deviation of the simulated from the observed values.

The Coefficient of Residual Mass (CRM) was used to measure the tendency of the model to over estimate or under estimate the measured values. The CRM is defined by

$$CRM = 100x \left( \sum_{i=1}^{n} M_i - \sum_{i=1}^{n} S_i \right) / \sum_{i=1}^{n} M_i$$

Where $M_i$ and $S_i$, are the measured and simulated values respectively for the $i^{th}$ data point of n observations. A negative CRM indicates a tendency of the model towards over estimation (Xevi *et al.*, 1996).

# IV. EXPERIMENTAL RESULTS

The field experiments were conducted during winter seasons of 1998-99 and 1999-2000 to investigate the "Effect of planting dates on growth and yield of maize varieties" and to find out the "Effect of irrigation scheduling, plant density and nitrogen levels on growth and yield of maize". Further, these experiments results were compared with the simulated results of DSSAT v 3.5 CERES maize models. The results obtained from these field experiments and CERES maize model simulation studies are presented in this chapter.

## 4.1 EFFECT OF PLANTING DATES ON GROWTH AND YIELD OF MAIZE VARIETIES

### 4.1.1 Plant height (cm) (cf. Table 1 and Appendix 5)

Plant height increased as the crop growth advanced, the magnitude of increase was nearly nine to ten times between 30 DAS and anthesis and the increase was marginal from anthesis to physiological maturity.

Plant height varied significantly between the varieties at all the growth stages in 1998-99, 1999-2000 and average of two years. At 30 DAS, DMH-1 recorded plant height (21.36 cm) on par with DMH-2 (21.11 cm) and was significantly higher than other varieties during both the years. At anthesis during 1998-99 DMH-2 registered higher plant height (231.33 cm) and was on par with DMH-1 (229.67 cm) and significantly higher than other varieties. While, during 1999-2000 season DMH-2 recorded plant height of 198.57 cm and was on par with DMH-1 (199.65 cm) and Deccan-103 (199.98 cm), and was significantly higher than Prabha (186.94 cm) and Renuka (170.67 cm). Similar trend existed at physiological maturity. Renuka recorded significantly shorter plant height at all the growth stages during both the years and over the years.

Among planting dates, during both the years and average over the years, at 30 DAS October I fortnight (26.13 and 21.53 cm during 1998-99 and 1999-2000 seasons respectively), at anthesis and physiological maturity during 1999-2000 and average of the two years November I fortnight registered significantly higher plant height (195.09 cm and 207.45 cm respectively) than others, while during 1998-99 though November I fortnight ($D_{3)}$ registered higher plant height (218.90 cm), it was on par with $D_1$ (219 cm), $D_2$ (219.13 cm), and $D_4$ (219.30 cm).

Interaction effect of D x V was significant at all the growth stages during both the years and average over the years. As the planting dates delayed there was significant reduction in plant height in all the varieties at 30 DAS during 1998-99, 1999-2000 and average of two years, significant plant height recorded in October-I fortnight physiological maturity November I fortnight planting with $V_1$, $V_2$, $V_3$ and $V_5$ and November II fortnight with $V_4$ recorded significantly higher plant height over other treatment combinations.

### 4.1.2 Number of leaves plant$^{-1}$ (cf. Table 2 and Appendix 6)

Number of leaves plant$^{-1}$ increased upto anthesis and remained constant at physiological maturity. At 30 DAS significantly higher number of leaves plant$^{-1}$ (9.19 leaves) were recorded with Renuka over others. Whereas, other varieties recorded on par number of leaves plant$^{-1}$ during both the seasons. At anthesis and physiological maturity, number of leaves plant$^{-1}$ recorded in DMH-1 (18.07 leaves), Deccan-103 (18.05 leaves), DMH-2 (18.08 leaves) and Prabha (18.07 leaves) were on par and were significantly higher than Renuka (13.26 leaves).

Significant differences between planting dates were observed at 30 DAS, anthesis and physiological maturity. At 30 DAS during 1998-99 significantly higher number of leaves plant$^{-1}$ (9.84 leaves) were noticed with October I fortnight planting over other planting dates. Similar trend was noticed during 1999-2000 and for average data of two years. At anthesis and physiological maturity number of leaves plant$^{-1}$ was significantly more in October I fortnight planting, than other dates during both the years and in average of two years.

**Table 1. Plant height (cm) of maize varieties at different growth stages as influenced by planting dates (pooled data of two years)**

| Growth stages | 30 DAS | | | | | Anthesis | | | | | Physiological maturity | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** |
| **$V_1$** | 24.33 | 20.83 | 19.50 | 17.33 | **20.50** | 214.33 | 214.17 | 215.96 | 210.67 | **213.78** | 214.33 | 214.17 | 215.96 | 210.67 | **213.78** |
| **$V_2$** | 25.17 | 22.50 | 20.50 | 17.25 | **21.36** | 213.00 | 216.17 | 217.30 | 212.17 | **214.66** | 213.00 | 216.17 | 217.30 | 212.17 | **214.66** |
| **$V_3$** | 25.17 | 22.50 | 19.50 | 17.25 | **21.11** | 213.33 | 215.17 | 218.13 | 213.17 | **214.95** | 213.33 | 215.17 | 218.13 | 213.17 | **214.95** |
| **$V_4$** | 24.50 | 21.83 | 18.17 | 16.25 | **20.19** | 204.17 | 200.67 | 206.17 | 216.22 | **206.81** | 204.17 | 200.67 | 206.17 | 216.22 | **206.81** |
| **$V_5$** | 20.00 | 17.50 | 16.83 | 15.25 | **17.40** | 175.67 | 177.50 | 179.67 | 172.33 | **176.29** | 175.67 | 177.50 | 179.67 | 172.33 | **176.29** |
| **Mean** | **23.83** | **21.03** | **18.90** | **16.67** | **20.11** | **204.10** | **204.74** | **207.45** | 205.30 | **205.30** | **204.10** | **204.74** | **207.45** | **204.91** | **205.30** |

| | 30 DAS | | Anthesis | | Physiological maturity | |
|---|---|---|---|---|---|---|
| **Comparing means of** | SEm ± | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Planting dates** | 0.212 | 0.651 | 0.829 | 2.553 | 0.829 | 2.553 |
| **Varieties** | 0.132 | 0.357 | 0.722 | 2.002 | 0.722 | 2.002 |
| **Planting dates x Varieties** | 0.265 | 0.734 | 1.445 | 4.004 | 1.445 | 4.004 |

DAS: Days after sowing

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

**Table 2. Number of leaves of maize varieties at different growth stages as influenced by planting dates (pooled data of two years)**

| Growth stages | 30 DAS | | | | | Anthesis | | | | | Physiological maturity | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** |
| **$V_1$** | 9.75 | 8.80 | 8.50 | 8.05 | **8.78** | 18.73 | 17.3 | 17.9 | 18.3 | **18.05** | 18.73 | 17.33 | 17.88 | 18.25 | **18.05** |
| **$V_2$** | 9.75 | 8.80 | 8.50 | 8.05 | **8.78** | 18.73 | 17.4 | 17.9 | 18.3 | **18.07** | 18.73 | 17.35 | 17.88 | 18.3 | **18.07** |
| **$V_3$** | 9.55 | 8.80 | 8.50 | 8.05 | **8.73** | 18.77 | 17.3 | 17.9 | 18.3 | **18.08** | 18.77 | 17.33 | 17.88 | 18.32 | **18.08** |
| **$V_4$** | 9.75 | 8.80 | 8.40 | 8.05 | **8.75** | 18.73 | 17.4 | 17.9 | 18.3 | **18.07** | 18.73 | 17.37 | 17.88 | 18.28 | **18.07** |
| **$V_5$** | 9.90 | 9.00 | 9.00 | 8.85 | **9.19** | 13.52 | 13.3 | 13.7 | 12.5 | **13.26** | 13.52 | 13.3 | 13.7 | 12.51 | **13.26** |
| **Mean** | **9.74** | **8.84** | **8.58** | **8.21** | **8.84** | **17.70** | **16.54** | **17.04** | **17.13** | **17.10** | **17.70** | **16.54** | **17.04** | **17.13** | **17.10** |

| | 30 DAS | | Anthesis | | Physiological maturity | |
|---|---|---|---|---|---|---|
| **Comparing means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Planting dates** | 0.131 | 0.403 | 0.118 | 0.345 | 0.118 | 0.345 |
| **Varieties** | 0.035 | 0.098 | 0.071 | 0.200 | 0.071 | 0.200 |
| **Planting dates x Varieties** | 0.070 | 0.196 | 0.143 | 0.399 | 0.143 | 0.399 |

DAS: Days after sowing

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

**Table 3. Leaf area index of maize varieties at different growth stages as influenced by planting dates (pooled data of two years)**

| Growth stages | 30 DAS | | | | | Anthesis | | | | | Physiological maturity | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** |
| **$V_1$** | 0.77 | 0.71 | 0.50 | 0.48 | **0.61** | 3.57 | 3.31 | 3.43 | 3.34 | **3.41** | 1.40 | 1.35 | 1.40 | 1.39 | **1.38** |
| **$V_2$** | 0.77 | 0.71 | 0.50 | 0.48 | **0.61** | 3.57 | 3.31 | 3.43 | 3.34 | **3.41** | 1.40 | 1.35 | 1.40 | 1.39 | **1.38** |
| **$V_3$** | 0.77 | 0.71 | 0.50 | 0.49 | **0.62** | 3.57 | 3.31 | 3.43 | 3.21 | **3.38** | 1.39 | 1.33 | 1.40 | 1.35 | **1.37** |
| **$V_4$** | 0.77 | 0.71 | 0.50 | 0.48 | **0.61** | 3.57 | 3.31 | 3.43 | 3.34 | **3.41** | 1.41 | 1.37 | 1.40 | 1.35 | **1.38** |
| **$V_5$** | 0.83 | 0.76 | 0.52 | 0.58 | **0.67** | 1.55 | 1.47 | 1.39 | 1.42 | **1.46** | 0.64 | 0.58 | 0.57 | 0.56 | **0.59** |
| **Mean** | **0.78** | **0.72** | **0.50** | **0.50** | **0.62** | **3.16** | **2.94** | **3.02** | **2.93** | **3.01** | **1.25** | **1.20** | **1.23** | **1.20** | **1.22** |

| | 30 DAS | | Anthesis | | Physiological maturity | |
|---|---|---|---|---|---|---|
| **Comparing means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Planting dates** | 0.0018 | 0.0055 | 0.0008 | 0.0024 | 0.0160 | 0.0493 |
| **Varieties** | 0.0005 | 0.0014 | 0.0034 | 0.0095 | 0.0191 | 0.0135 |
| **Planting dates x Varieties** | 0.0010 | 0.0028 | 0.0067 | 0.0187 | 0.0383 | 0.1072 |

DAS: Days after sowing

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

The interaction effect of planting dates and varieties were significant at all the growth stages during both the years and in pooled data over two years. At 30 DAS, in 1998-99 October I fortnight planting with Renuka ($D_1V_5$) recorded significantly higher number of leaves plant$^{-1}$ (10 leaves) over other interactions. During 1999-2000 October I fortnight with Renuka ($D_1V_5$) recorded on par number of leaves plant$^{-1}$ (9.8 leaves) with other interactions such as $D_1$ x $V_1$ (9.7 leaves), $D_1$ x $V_3$ (9.7 leaves), $D_1$ x $V_1$ (9.7 leaves) and $D_1$ x $V_4$ (9.7 leaves), and these were significantly higher than other interaction effects. Similar trend was observed in pooled data. At anthesis and physiological maturity during 1998-99 $D_1$ x $V_1$, $D_1$ x $V_2$, $D_1$ x $V_4$ and $D_1$ x $V_3$ registered on par number of leaves plant$^{-1}$. However, these were significantly higher than other interactions. While, during 1999-2000 $D_1$ x $V_1$, $D_1$ x $V_2$, $D_1$ x $V_4$, $D_1$ x $V_3$, $D_4$ x $V_1$, $D_4$ x $V_2$, $D_4$ x $V_3$ and $D_4$ x $V_4$ interactions were on par and recorded significantly higher number of leaves plant$^{-1}$ than others.

### 4.1.3 Leaf area index (LAI) (cf. Table 3 and Appendix 7)

Leaf area index of maize increased upto anthesis and remarkably reduced at physiological maturity. Significantly higher LAI was recorded with Renuka at 30 DAS during both the years. At anthesis, Deccan-103, DMH-1, DMH-2 and Prabha during 1998-99, and Deccan-103, DMH-1, Prabha and DMH-2 during 1999-2000 recoded significantly higher LAI than Renuka. At physiological maturity, there was decline in LAI, however the trend was similar as that of anthesis.

The LAI differed significantly with planting dates at all the growth stages. Among the planting dates, at 30 DAS and anthesis October I fortnight planting ($D_1$) recorded significantly higher LAI during both the years and average over the years. While, at physiological maturity, October I fortnight planting registered significantly higher LAI during 1998-99, whereas during 1999-2000 November I fortnight planting ($D_3$) recorded higher LAI. The pooled data indicated that November I fortnight recorded on par LAI with October I fortnight planting and was significantly higher than either October II or November II fortnight planting dates.

The interaction effects of D x V were also significant. At 30 DAS, Renuka with October I fortnight planting ($D_1$ x $V_5$) during both the years and average over the years recorded significantly higher LAI over other interactions. At anthesis, $D_1$ x $V_1$, $D_1$ x $V_2$, $D_1$ x $V_3$ and $D_1$ x $V_4$; at physiological maturity $D_1$ x $V_1$ and $D_3$ x $V_3$ during 1998-99 and $D_1$ x $V_3$, $D_4$ x $V_3$ and $D_3$ x $V_4$ during 1999-2000 recorded higher LAI as compared to other interactions.

### 4.1.4 Dry matter (g plant$^{-1}$)

#### 4.1.4.1 At 30 DAS (cf. Table 4 and Appendix 8)

Total dry matter plant$^{-1}$ varied between varieties. Renuka recorded higher total dry matter plant$^{-1}$ as compared to other varieties which were on par with each other during 1998-99 and 1999-2000 and average of the two years.

Similarly, total dry matter plant$^{-1}$ varied significantly between planting dates. Planting during October I fortnight recorded significantly higher total dry matter plant$^{-1}$ followed by November I fortnight. Significantly lower dry matter plant$^{-1}$ was recorded in November II fortnight planting during both the years and average of the two years.

The interaction effects were significant. Renuka sown during October I fortnight ($D_1$ x $V_5$) recorded significantly higher dry matter plant$^{-1}$ during both the years and average over the two years as compared to other interaction effects.

#### 4.1.4.2 Anthesis (cf. Table 4 and Appendix 8)

There was significant difference in total dry matter plant$^{-1}$ among different varieties during both the years and average over two years. Deccan-103, DMH-1, Prabha recorded on par total dry matter plant$^{-1}$ and next in order was DMH-2 and these were significantly higher than Renuka.

Total dry matter plant$^{-1}$ recorded at anthesis differed significantly with planting dates. During 1998-99, significantly higher dry matter plant$^{-1}$ was obtained with October I fortnight compared to other planting dates.

During 1999-2000, October I fortnight and November I fortnight planting dates recorded on par total dry matter plant$^{-1}$ and these were significantly higher over other planting dates. The results recorded in pooled data over two years were as that of 1998-99.

The interaction of $D_1$x $V_1$, $D_1$ x $V_2$ and $D_1$ x $V_4$ recorded significantly higher total dry matter plant$^{-1}$ compared to other interactions during both the years.

### 4.1.4.3 Physiological maturity

At physiological maturity, total dry matter plant$^{-1}$ and its partitioning to leaf, stem and cobs were found to vary significantly with planting dates and varieties.

#### 4.1.4.3.1 Leaf dry matter plant$^{-1}$ (cf Table 5 and Appendix 9)

Among the varieties Deccan-103, DMH-1 and Prabha recorded significantly higher leaf dry matter (g plant$^{-1}$) compared to DMH-2. However, Renuka obtained significantly lower leaf dry matter plant$^{-1}$. The trend was similar during both the years and average of the two years.

Significantly higher leaf dry matter plant$^{-1}$ was obtained for October I fortnight as compared to November II fortnight, November I fortnight and October II fortnight during 1998-99. However, during 1999-2000, November I fortnight planting recorded significantly higher leaf dry matter plant$^{-1}$ as compared to other planting dates. In the pooled data, November I fortnight and October I fortnight recorded on par leaf dry matter plant$^{-1}$ and were significantly higher than other planting dates.

The planting dates and varieties interaction varied significantly. November II fortnight with Deccan-103, November II fortnight with DMH-1 during 1998-99 and October I fortnight with Deccan-103, October I fortnight with DMH-1 and October I fortnight with Prabha during 1999-2000 recorded significantly higher leaf dry matter plant$^{-1}$ compared to other interactions. The average data over two years indicated that October I fortnight with Deccan-103, October I fortnight with DMH-1 and October I fortnight with Prabha registered on par and significantly higher leaf dry matter plant$^{-1}$ as compared to other interactions.

#### 4.1.4.3.2 Stem dry matter plant$^{-1}$ (cf Table 5 and Appendix 9)

Among the varieties, during both the years and average over the two years Deccan-103, DMH-1 and Prabha registered on par stem dry matter plant$^{-1}$ between each other but were significantly higher over others.

Significant differences in stem dry matter were noticed due to planting dates. October I fortnight planting during 1998-99 recorded significantly higher stem dry matter plant-$^{1}$. During 1999-2000 October I fortnight and November I fortnight were on par and were significantly higher as compared to October II fortnight planting. Pooled data also indicated similar results as that of 1999-2000.

The interaction effect of D x V was significant during both the years October I fortnight with Deccan-103, October I fortnight with DMH-1 and October I fortnight with Prabha recorded on par stem dry matter plant$^{-1}$ and were higher as compared to other interaction effects.

#### 4.1.4.3.3 Cob dry matter plant$^{-1}$ (cf Table 5 and Appendix 9)

The cob dry matter plant$^{-1}$ at physiological maturity differed significantly due to planting dates and varieties. Among the varieties DMH-2 recorded significantly higher cob dry matter plant-$^{1}$ during both the years and average over two years.

During 1998-99 higher cob dry matter plant$^{-1}$ was recorded with October I fortnight and which was on par with October II fortnight planting date, however, these were significantly higher over others. During 1999-2000 statistically on par cob dry matter plant$^{-1}$ was registered between October II fortnight, November I fortnight and November II fortnight and these were significantly higher than October I fortnight planting date. Average data over two years indicated that October I fortnight and October II fortnight recorded on par cob dry matter plant$^{-1}$ and were significantly higher as compared to November I fortnight and November II fortnight planting dates.

Interaction effects of D x V were also significant during both the years and average of two years. During 1998-99, October I fortnight with DMH-2 and October II fortnight with DMH-2, during 1999-2000 November II fortnight with DMH-2 and in average data over two years October I fortnight with DMH-2 and October II fortnight with DMH-2 interactions recorded significantly higher cob dry matter plant$^{-1}$ over others and they themselves were on par.

4.1.4.3.4 Total dry matter plant$^{-1}$ (cf Table 4 and Appendix 8)

Total dry matter plant$^{-1}$ at physiological maturity differed significantly due to planting dates and varieties. Among the varieties, significantly higher total dry matter plant$^{-1}$ was recorded with DMH-2 during 1998-99 and 1999-2000 seasons; next in the order were DMH-1, Deccan-103 and Prabha. Significantly lower total dry matter plant$^{-1}$ was recorded with Renuka compared to other varieties. The average data over two years also indicated similar trend.

During 1998-99 significantly higher total dry matter plant$^{-1}$ was obtained in October I fortnight, which was followed by October II fortnight, November I fortnight and November II fortnight. However, during 1999-2000 significantly higher total dry matter plant$^{-1}$ was registered in November I fortnight followed by October I fortnight and next in order were October II fortnight and November II fortnight, and these later two planting dates were on par. Over the two years, the trend observed was similar to that of 1998-99.

The interaction between planting dates and varieties differed significantly. Planting of DMH-2 in all the planting dates recorded significantly higher total dry matter plant$^{-1}$ over planting of other varieties at all the dates of planting. However, the total dry matter plant$^{-1}$ recorded in $D_1$ x $V_{3,}$ $D_2$ x $V_3$ and $D_3$ x $V_3$ were on par and were significantly higher than other interactions.

## 4.1.5 Phenological stages

The phenological stages such as days to 50 per cent flowering and days to physiological maturity significantly varied due to planting dates and varieties.

4.1.5.1 Days to 50 per cent flowering (cf. Table 6)

Among the varieties, Deccan-103, DMH-1 and Prabha took similar number of days to 50 per cent flowering and were significantly higher as compared to DMH-2 and Renuka during both the seasons. Similar trend was noticed in average for two years.

During 1998-99 season significantly more days to 50 per cent flowering was registered in November II fortnight and November I fortnight than October I fortnight and October II fortnight planting. During 1999-2000 November I fortnight recorded significantly more number of days to 50 per cent flowering than other planting dates. Average over two years, November II fortnight recorded significantly more days to 50 per cent flowering than November I fortnight, October II fortnight and October I fortnight planting dates.

The interaction effect of D x V was significant during both the years. Average over two years, November I fortnight planting of all the varieties except Renuka and November II fortnight planting of Deccan-103, DMH-1 and Prabha recorded on par number of days to 50 per cent flowering and were significantly higher over other interactions.

4.1.5.2 Days to physiological maturity (cf. Table 7)

Days to physiological maturity differed significantly due to planting dates and varieties. Among the varieties, DMH-2 during both the years registered more days to physiological maturity compared to other varieties. However, Renuka took significantly lower number of days to physiological maturity.

As the planting dates delayed there was progressive reduction in days to physiological maturity. Similar trend was noticed during both the years. November II fortnight recorded significant reduction in days to physiological maturity as compared to October I

**Table 4. Total dry matter (g plant$^{-1}$) of maize varieties at different growth stages as influenced by planting dates (Pooled data of two years)**

| Growth stages | 30 DAS | | | | | Anthesis | | | | | Physiological maturity | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| $V_1$ | 8.62 | 6.13 | 7.30 | 4.85 | **6.73** | 114.55 | 104.80 | 111.03 | 109.47 | **109.96** | 269.67 | 263.07 | 269.35 | 262.41 | **266.13** |
| $V_2$ | 8.68 | 6.25 | 7.33 | 4.90 | **6.79** | 114.65 | 104.90 | 111.18 | 109.57 | **110.08** | 285.78 | 278.46 | 276.40 | 277.55 | **279.55** |
| $V_3$ | 8.77 | 6.25 | 7.33 | 4.90 | **6.81** | 107.40 | 104.90 | 111.18 | 106.52 | **107.50** | 288.96 | 289.29 | 288.82 | 282.78 | **287.46** |
| $V_4$ | 8.63 | 6.38 | 7.30 | 4.85 | **6.79** | 114.55 | 104.80 | 111.03 | 109.47 | **109.96** | 260.64 | 253.91 | 253.93 | 261.71 | **257.55** |
| $V_5$ | 10.20 | 7.27 | 7.87 | 7.37 | **8.18** | 55.75 | 50.60 | 49.82 | 48.62 | **51.20** | 162.42 | 148.83 | 152.88 | 145.73 | **152.47** |
| **Mean** | **8.98** | **6.46** | **7.43** | **5.37** | **7.06** | **101.38** | **94.00** | **98.85** | **96.73** | **97.74** | **253.49** | **246.71** | **248.28** | **246.04** | **248.63** |

| | 30 DAS | | Anthesis | | Physiological maturity | |
|---|---|---|---|---|---|---|
| **Comparing means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Planting dates** | 0.019 | 0.057 | 0.015 | 0.046 | 0.097 | 0.300 |
| **Varieties** | 0.019 | 0.053 | 0.190 | 0.531 | 0.232 | 0.649 |
| **Planting dates x Varieties** | 0.038 | 0.106 | 0.379 | 1.062 | 0.463 | 1.297 |

DAS: Days after sowing

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

**Table 5. Dry matter production(g plant$^{-1}$) in different plant parts of maize varieties at physiological maturity as influenced by planting dates(pooled data of two years)**

| Growth stages | Leaf dry matter (g plant$^{-1}$) | | | | | Stem dry matter (g plant$^{-1}$) | | | | | Cob dry matter (g plant$^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** |
| **$V_1$** | 42.48 | 38.93 | 42.15 | 41.63 | **41.30** | 60.87 | 57.62 | 59.73 | 58.65 | **59.22** | 166.32 | 166.52 | 167.47 | 162.13 | **165.61** |
| **$V_2$** | 42.50 | 38.93 | 42.15 | 41.63 | **41.30** | 60.78 | 56.78 | 59.60 | 57.85 | **58.75** | 182.50 | 182.75 | 174.65 | 178.07 | **179.49** |
| **$V_3$** | 38.83 | 38.68 | 41.93 | 39.18 | **39.66** | 57.80 | 54.63 | 58.31 | 54.22 | **56.24** | 192.33 | 195.98 | 188.58 | 189.38 | **191.57** |
| **$V_4$** | 42.50 | 38.92 | 42.10 | 41.53 | **41.26** | 60.87 | 57.32 | 59.70 | 58.60 | **59.12** | 157.27 | 157.67 | 152.13 | 161.58 | **157.16** |
| **$V_5$** | 14.57 | 13.57 | 12.72 | 13.45 | **13.58** | 39.95 | 36.98 | 37.58 | 35.18 | **37.42** | 107.90 | 98.28 | 102.58 | 97.10 | **101.47** |
| **Mean** | **36.18** | **33.81** | **36.21** | **35.48** | **35.42** | **56.05** | **52.67** | **54.98** | **52.90** | **54.15** | **161.26** | **160.24** | **157.08** | **157.65** | **159.06** |

| | Leaf dry matter | | Stem dry matter | | Cob dry matter | |
|---|---|---|---|---|---|---|
| **Comparing means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Planting dates** | 0.012 | 0.036 | 0.194 | 0.597 | 0.533 | 1.642 |
| **Varieties** | 0.046 | 0.130 | 0.331 | 0.926 | 0.623 | 1.743 |
| **Planting dates x Varieties** | 0.093 | 0.260 | 0.662 | 1.853 | 1.245 | 3.487 |

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

## Table 6. Days to 50% flowering of maize varieties as influenced by planting dates

| Year | 1998-99 | | | | | 1999-2000 | | | | | Pooled | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| $V_1$ | 69.00 | 69.00 | 74.00 | 74.00 | **71.50** | 70.00 | 70.00 | 71.00 | 70.00 | **70.25** | 69.50 | 69.50 | 72.50 | 72.00 | **70.88** |
| $V_2$ | 69.00 | 69.00 | 74.00 | 74.00 | **71.50** | 70.00 | 70.00 | 71.00 | 70.00 | **70.25** | 69.50 | 69.50 | 72.50 | 72.00 | **70.88** |
| $V_3$ | 66.00 | 69.00 | 74.00 | 71.00 | **70.00** | 66.00 | 70.00 | 71.00 | 70.00 | **69.25** | 66.00 | 69.50 | 72.50 | 70.50 | **69.63** |
| $V_4$ | 69.00 | 69.00 | 74.00 | 74.00 | **71.50** | 70.00 | 70.00 | 71.00 | 70.00 | **70.25** | 69.50 | 69.50 | 72.50 | 72.00 | **70.88** |
| $V_5$ | 48.00 | 47.00 | 45.00 | 52.00 | **48.00** | 47.00 | 48.00 | 52.00 | 49.00 | **49.00** | 47.50 | 47.50 | 48.50 | 50.50 | **48.50** |
| **Mean** | **64.20** | **64.60** | **68.20** | **69.00** | **66.50** | **64.60** | **65.60** | **67.20** | **65.80** | **65.80** | **64.40** | **65.10** | **67.70** | **67.40** | **66.15** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Planting dates** | 0.067 | 0.231 | 0.137 | 0.824 | 0.076 | 0.235 |
| **Varieties** | 0.095 | 0.263 | 0.065 | 0.179 | 0.574 | 1.590 |
| **Planting dates x Varieties** | 0.190 | 0.527 | 0.129 | 0.358 | 0.115 | 0.319 |

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

**Table 7. Days to physiological maturity of maize varieties as influenced by planting dates**

| Year | 1998-99 | | | | | 1999-2000 | | | | | Pooled | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** |
| **$V_1$** | 136 | 131 | 129 | 123 | **130** | 135 | 131 | 128 | 124 | **129** | 135 | 131 | 129 | 124 | **130** |
| **$V_2$** | 136 | 131 | 129 | 123 | **130** | 135 | 131 | 128 | 124 | **129** | 135 | 131 | 129 | 124 | **129** |
| **$V_3$** | 139 | 136 | 133 | 127 | **133** | 138 | 135 | 134 | 128 | **134** | 138 | 136 | 133 | 128 | **134** |
| **$V_4$** | 136 | 131 | 129 | 124 | **130** | 135 | 131 | 130 | 124 | **130** | 136 | 131 | 129 | 124 | **130** |
| **$V_5$** | 104 | 102 | 100 | 99 | **101** | 101 | 99 | 100 | 95 | **99** | 103 | 101 | 100 | 97 | **100** |
| **Mean** | **130** | **126** | **124** | **119** | **125** | **129** | **125** | **124** | **119** | **124** | **129** | **126** | **124** | **119** | **125** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Planting dates** | 0.218 | 0.756 | 0.163 | 0.565 | 0.136 | 0.420 |
| **Varieties** | 0.169 | 0.490 | 0.118 | 0.340 | 0.103 | 0.289 |
| **Planting dates x Varieties** | 0.339 | 0.980 | 0.235 | 0.680 | 0.206 | 0.578 |

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

The interaction effects between planting dates and varieties differed significantly. Renuka planted during November II fortnight recorded significantly lower number of days for physiological maturity whereas DMH-2 planted on October I fortnight recorded significantly more number of days to physiological maturity as compared to other interactions.

## 4.1.6 Yield and yield parameters

### 4.1.6.1 Grain yield (kg $ha^{-1}$) (cf. Table 8)

Grain yield differed significantly due to planting dates and varieties. Among the varieties, during 1998-99 and 1999-2000 DMH-2 recorded significantly superior grain yield (7847 and 8534 kg $ha^{-l}$ respectively) over DMH-1 (7184 and 7832 kg $ha^{-l}$ respectively), Deccan-103 (6352 and 7004 kg $ha^{-l}$ respectively) and Prabha (6091 and 6508 kg $ha^{-1}$ respectively). Significantly lower grain yield (3597 and 3767 kg $ha^{-l}$ respectively) was observed with Renuka ($V_5$). The trend was similar for the mean values,

During 1998-99, significantly superior grain yield (6569 kg $ha^{-l}$) was obtained with October I fortnight ($D_l$) as compared to other planting dates. However during 1999-2000, October II fortnight (6823 kg $ha^{-l}$) and October I fortnight (6736 kg $ha^{-l}$) recorded on par grain yield and which were significantly higher over November I fortnight (6641 kg $ha^{-l}$) and November II fortnight (6715 kg $ha^{-l}$). Average over the years, October 1st fortnight (6653 kg $ha^{-l}$) registered on par grain yield with October II fortnight (6630 kg $ha^{-l}$) and were significantly superior over other planting dates. Grain yield of November I fortnight (6285 kg $ha^{-l}$) and November II fortnight (6319 kg $ha^{-l}$) planting dates did not differ significantly.

Interaction of planting dates and varieties was significant during both the years. During 1998-99 and 1999-2000 October II fortnight with DMH-2 ($D_2$ x $V_3$) recorded significantly superior grain yield (8320 and 8786 kg $ha^{-l}$ respectively). Similarly, in the average over two years October II fortnight with DMH-2 recorded significantly higher grain yield (8553 kg $ha^{-l}$), and next in order were October I fortnight with DMH-2 (8255 kg $ha^{-1}$), November II fortnight with DMH-2 (8014 kg $ha^{-l}$). However, November II fortnight with Renuka ($D_4$ x $V_5$) recorded significantly lower grain yield (3433 kg $ha^{-1}$) compared to other interactions.

### 4.1.6.2 Stover yield (kg $ha^{-l}$) (cf. Table 9)

Stover yield differed significantly due to planting dates and varieties. During 1998-99 DMH-1 recorded higher stover yield (7847 kg $ha^{-l}$) and it was on par with Prabha (7805 kg $ha^{-l}$) and Deccan-103 (7798 kg $ha^{-1}$)significantly superior over DMH-2 (7567 kg $ha^{-l}$). However, during 1999-2000 stover yield of Deccan-103(7901 kg $ha^{-l}$), Prabha (7891 kg $ha^{-l}$) and DMH-1 (7861 kg $ha^{-l}$) was on par and significantly superior over DMH-2 (7654 kg $ha^{-1}$). While, Renuka recorded significantly lower stover yield (4722 and 4800 kg $ha^{-l}$) respectively compared to other varieties. The pooled stover yield showed similar trend as that of 1998-99.

Among planting dates during 1998-99, October I fortnight ($D_1$) recorded significantly higher stover yield (7406 kg $ha^{-1}$) over other planting dates. During 1999-2000, November I fortnight ($D_3$) registered significantly superior stover yield (7363 kg $ha^{-1}$), over October I fortnight (7299 kg $ha^{-1}$), October II fortnight (7191 kg $ha^{-1}$) and November II fortnight (6971 kg $ha^{-1}$). Average over two years, October I fortnight ($D_l$) recorded significantly higher stover yield (7352 kg $ha^{-1}$) over other planting dates.

The interaction effect between planting dates and varieties was significant. October I fortnight with Prabha (8048 kg $ha^{-l}$), October I fortnight with DMH-1 (8042 kg $ha^{-l}$) and October I fortnight with Deccan-l03 (8040 kg $ha^{-l}$) during 1998-99 recorded on par stover yield, and were significantly superior over other treatment combinations. During 1999-2000, the stover yield registered for October I fortnight with DMH-1 (8011 kg $ha^{-l}$), October I fortnight with Deccan-103 (8008 kg $ha^{-l}$) and October I. fortnight with Prabha (7966 kg $ha^{-1}$) were on par with November I fortnight with Prabha (7997 kg $ha^{-l}$) and November I fortnight with Deccan-103 (7959 kg $ha^{-l}$), These interactions were significantly superior over other interaction effects. The trend for the average data over two years was similar as that of 1998-99.

## Table 8. Grain yield (kg $ha^{-1}$) of maize varieties as influenced by planting dates

| Year | 1998-99 | | | | | 1999-2000 | | | | | Pooled | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** |
| **$V_1$** | 6634 | 6532 | 6133 | 6109 | **6352** | 7009 | 7088 | 6922 | 6997 | **7004** | 6822 | 6810 | 6528 | 6553 | **6678** |
| **$V_2$** | 7531 | 7524 | 6720 | 6961 | **7184** | 7798 | 7892 | 7706 | 7930 | **7832** | 7665 | 7708 | 7213 | 7446 | **7508** |
| **$V_3$** | 8116 | 8320 | 7562 | 7389 | **7847** | 8394 | 8786 | 8465 | 8492 | **8534** | 8255 | 8553 | 8014 | 7941 | **8191** |
| **$V_4$** | 6428 | 6317 | 5811 | 5807 | **6091** | 6474 | 6531 | 6389 | 6637 | **6508** | 6451 | 6424 | 6100 | 6222 | **6299** |
| **$V_5$** | 4137 | 3487 | 3416 | 3348 | **3597** | 4006 | 3820 | 3724 | 3517 | **3767** | 4072 | 3654 | 3570 | 3433 | **3682** |
| **Mean** | **6569** | **6436** | **5928** | **5923** | **6214** | **6736** | **6823** | **6641** | **6715** | **6729** | **6653** | **6630** | **6285** | **6319** | **6471** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Planting dates** | 21.61 | 74.81 | 31.12 | 107.69 | 18.94 | 58.38 |
| **Varieties** | 26.25 | 75.82 | 21.85 | 63.12 | 17.08 | 47.82 |
| **Planting dates x Varieties** | 52.51 | 151.64 | 43.71 | 126.24 | 34.16 | 95.66 |

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

## Table 9. Stover yield (kg ha$^{-1}$) of maize varieties as influenced by planting dates

| Year | 1998-99 | | | | | 1999-2000 | | | | | Pooled | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| $V_1$ | 8040 | 7484 | 7898 | 7768 | **7798** | 8008 | 7842 | 7959 | 7795 | **7901** | 8024 | 7663 | 7929 | 7782 | **7849** |
| $V_2$ | 8042 | 7651 | 7919 | 7777 | **7847** | 8011 | 7796 | 7938 | 7697 | **7861** | 8027 | 7724 | 7929 | 7737 | **7854** |
| $V_3$ | 7648 | 7370 | 7867 | 7382 | **7567** | 7698 | 7633 | 7830 | 7456 | **7654** | 7673 | 7502 | 7849 | 7419 | **7611** |
| $V_4$ | 8048 | 7498 | 7896 | 7776 | **7805** | 7997 | 7828 | 7966 | 7774 | **7891** | 8023 | 7663 | 7931 | 7775 | **7848** |
| $V_5$ | 5252 | 4491 | 4505 | 4951 | **4800** | 4779 | 4856 | 5120 | 4134 | **4722** | 5016 | 4674 | 4813 | 4543 | **4761** |
| **Mean** | **7406** | **6899** | **7217** | **7131** | **7163** | **7299** | **7191** | **7363** | **6971** | **7206** | **7352** | **7045** | **7290** | **7051** | **7185** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Planting dates** | 20.29 | 70.23 | 12.96 | 44.87 | 12.04 | 37.11 |
| **Varieties** | 19.85 | 57.34 | 11.65 | 33.65 | 11.51 | 32.23 |
| **Planting dates x Varieties** | 39.71 | 114.68 | 23.31 | 67.31 | 23.04 | 64.47 |

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

## Table 10. Biomass yield (kg $ha^{-1}$) of maize varieties as influenced by planting dates

| Year | 1998-99 | | | | | 1999-2000 | | | | | Pooled | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** |
| **$V_1$** | 14674 | 14016 | 14031 | 13877 | **14150** | 15017 | 14930 | 14881 | 14792 | **14905** | 14846 | 14473 | 14456 | 14335 | **14527** |
| **$V_2$** | 15573 | 15175 | 14639 | 14738 | **15031** | 15809 | 15688 | 15644 | 15627 | **15692** | 15691 | 15432 | 15142 | 15183 | **15362** |
| **$V_3$** | 15764 | 15690 | 15429 | 14771 | **15414** | 16092 | 16419 | 16295 | 15948 | **16189** | 15928 | 16055 | 15862 | 15360 | **15801** |
| **$V_4$** | 14476 | 13815 | 13707 | 13583 | **13895** | 14471 | 14359 | 14355 | 14411 | **14399** | 14474 | 14087 | 14031 | 13997 | **14147** |
| **$V_5$** | 9389 | 7978 | 7921 | 8299 | **8397** | 8785 | 8676 | 8844 | 7651 | **8489** | 9087 | 8327 | 8383 | 7975 | **8443** |
| **Mean** | **13975** | **13335** | **13145** | **13054** | **13377** | **14035** | **14014** | **14004** | **13686** | **13935** | **14005** | **13675** | **13575** | **13370** | **13656** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Planting dates** | 39.05 | 135.13 | 34.87 | 120.67 | 26.17 | 80.66 |
| **Varieties** | 49.14 | 141.91 | 26.26 | 75.83 | 27.85 | 78.01 |
| **Planting dates x Varieties** | 98.28 | 283.83 | 52.52 | 151.66 | 55.71 | 156.02 |

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

**Table 11. Harvest index of maize varieties as influenced by planting dates**

| Year | 1998-99 | | | | | 1999-2000 | | | | | Pooled | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** |
| **$V_1$** | 0.452 | 0.466 | 0.437 | 0.440 | **0.449** | 0.467 | 0.475 | 0.465 | 0.473 | **0.470** | 0.459 | 0.470 | 0.451 | 0.457 | **0.459** |
| **$V_2$** | 0.484 | 0.496 | 0.459 | 0.472 | **0.478** | 0.493 | 0.503 | 0.493 | 0.507 | **0.499** | 0.488 | 0.499 | 0.476 | 0.490 | **0.488** |
| **$V_3$** | 0.515 | 0.530 | 0.490 | 0.500 | **0.509** | 0.522 | 0.535 | 0.519 | 0.532 | **0.527** | 0.518 | 0.533 | 0.505 | 0.516 | **0.518** |
| **$V_4$** | 0.444 | 0.457 | 0.424 | 0.428 | **0.438** | 0.447 | 0.455 | 0.445 | 0.461 | **0.452** | 0.446 | 0.456 | 0.435 | 0.444 | **0.445** |
| **$V_5$** | 0.441 | 0.437 | 0.431 | 0.403 | **0.428** | 0.456 | 0.440 | 0.421 | 0.460 | **0.444** | 0.448 | 0.439 | 0.426 | 0.432 | **0.436** |
| **Mean** | **0.467** | **0.477** | **0.448** | **0.449** | **0.460** | **0.477** | **0.482** | **0.469** | **0.487** | **0.478** | **0.472** | **0.479** | **0.458** | **0.468** | **0.469** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Planting dates** | 0.0013 | 0.0044 | 0.0020 | 0.0069 | 0.0012 | 0.0036 |
| **Varieties** | 0.0023 | 0.0066 | 0.0015 | 0.0043 | 0.0014 | 0.0039 |
| **Planting dates x Varieties** | 0.0046 | 0.0132 | 0.0030 | 0.0086 | 0.0028 | 0.0078 |

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

4.1.6.3 Total biomass yield (kg ha$^{-l}$) (cf. Table 10)

The total biomass yield of maize differed significantly due to planting dates and varieties. DMH-2 recorded significantly higher total biomass yield during 1998-99, 1999-2000 and average over the seasons (15414, 16189 and 15801 kg ha$^{-l}$ respectively). Corresponding to the year and mean over two years, next in the order were DMH-1 (15031, 15692 and 15362 kg ha$^{-l}$ respectively) and Deccan-103 (14150, 14905 and 14527 kg ha$^{-l}$ respectively). Prabha stood fourth in order (13895, 14399 and 14147 kg ha$^{-l}$ respectively) and Renuka was least among the varieties (8397,8489 and 8443 kg ha$^{-l}$ respectively).

Among planting dates, significantly higher biomass yield was obtained in October I fortnight planting during 1998-99 and average over the years (13975 and 14005 kg ha$^{-l}$ respectively). However, during 1999- 2000 October I fortnight (14035kg ha$^{-l}$) was on par with October II fortnight (14014 kg ha$^{-l}$) and November I fortnight (14004 kg ha$^{-l}$).

The interaction effect due to planting dates and varieties caused significant difference in total biomass yield. October I fortnight x DMH-2 (15764 kg ha$^{-l}$), October II fortnight x DMH-2 (15690 kg ha$^{-l}$) and October I fortnight x DMH-1 (15573 kg ha$^{-l}$) interaction effects recorded on par biomass yield and were significantly higher over other treatment combinations during 1998-99. During 1999-2000 October II fortnights x DMH-2 (16419 kg ha$^{-l}$) and November II fortnight x DMH-2, (16295 kg ha$^{-l}$) recorded on par biomass yield and were significantly higher compared to other interaction effects. Average over the years, October II fortnight x DMH-2 (16055 kg ha$^{-l}$) and October I fortnight (15928 kg ha$^{-l}$) recorded on par yield and these interactions were significantly superior over other interactions.

4.1.6.4 Harvest index (cf. Table 11)

The harvest index differed significantly for planting dates and varieties. The harvest index varied significantly among the varieties during both the years, however the trend was similar for the mean of two years. When compared over the years significantly higher harvest index was recorded in DMH-2 (0.518) over DMH-1 (0.488), Deccan-103 (0.459) and Prabha (0.445). However, Renuka recorded least harvest index (0.436).

During 1998-99, higher harvest index was obtained for October II fortnight planting (0.477), next in order was October I fortnight (0.467), and were significantly higher over other planting dates. The November I fortnight ($D_3$) and November II fortnight ($D_4$) recorded on par harvest index of 0.448 and 0.449 respectively. During 1999-2000 higher harvest index was registered with November II fortnight (0.487) as compared to October I fortnight (0.477) and October II fortnight (0.482). When compared over the years, October II fortnight (0.479) and October I fortnight (0.472) recorded on par harvest index and which was significantly higher over November II fortnight (0.468) and November I fortnight (0.458).

The interaction effects of planting dates and varieties (DxV) were significant. During 1998-99 significantly higher harvest index was obtained in October II fortnight x DMH-2 (0.530) as compared to other interaction effects. During 1999-2000, significantly higher harvest index was recorded in October II fortnight x DMH-2 (0.535) over other interactions and was on par with November II fortnight x DMH-2 (0.532). Similarly when averaged over two years, higher harvest index was recorded with October II fortnight x DMH-2 (0.533), followed by October I fortnight x DMH-2 (0.518) and November II fortnight x DMH-2 (0.516). These were significantly higher than other interaction effects.

4.1.6.5 Grain weight (g grain$^{-1}$) (cf. Table 12)

The dry grain weight differed significantly with planting dates and varieties. Among the varieties, the trend was same during both the years. When averaged over two years, DMH-2 recorded significantly higher grain weight (0.318 g grain$^{-1}$) and was followed by DMH-I (0.285 g grain$^{-1}$), Deccan-103 (0.266 g grain$^{-1}$), Prabha (0.242 g grain$^{-1}$). Significantly least grain weight was with Renuka (0.202 g grain$^{-1}$).

The grain weight declined with a delay in planting dates from October I fortnight to November II fortnight. The trend was similar during both the years and when averaged over the years. October I fortnight recorded significantly higher grain weight (0.289 g grain$^{-1}$) followed by October II fortnight (0.272 g grain$^{-1}$) and November I fortnight (0.252 g grain$^{-1}$). Significantly lower grain weight was with November II fortnight (0.237 g grain$^{-1}$).

## Table 12. Grain weight (g) of maize varieties as influenced by planting dates

| Year | 1998-99 | | | | | 1999-2000 | | | | | Pooled | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| $V_1$ | 0.298 | 0.272 | 0.250 | 0.232 | **0.263** | 0.291 | 0.274 | 0.268 | 0.242 | **0.269** | 0.294 | 0.273 | 0.259 | 0.237 | **0.266** |
| $V_2$ | 0.317 | 0.298 | 0.263 | 0.250 | **0.282** | 0.310 | 0.293 | 0.285 | 0.265 | **0.288** | 0.314 | 0.295 | 0.274 | 0.258 | **0.285** |
| $V_3$ | 0.357 | 0.331 | 0.294 | 0.288 | **0.318** | 0.338 | 0.325 | 0.310 | 0.296 | **0.317** | 0.348 | 0.328 | 0.302 | 0.292 | **0.318** |
| $V_4$ | 0.272 | 0.252 | 0.232 | 0.211 | **0.242** | 0.260 | 0.244 | 0.239 | 0.224 | **0.242** | 0.266 | 0.248 | 0.235 | 0.218 | **0.242** |
| $V_5$ | 0.234 | 0.216 | 0.196 | 0.178 | **0.206** | 0.216 | 0.212 | 0.182 | 0.185 | **0.199** | 0.225 | 0.214 | 0.189 | 0.181 | **0.202** |
| **Mean** | **0.296** | **0.274** | **0.247** | **0.232** | **0.262** | **0.283** | **0.270** | **0.257** | **0.242** | **0.263** | **0.289** | **0.272** | **0.252** | **0.237** | **0.263** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing means of** | SEm ± | CD (0.05) | SEm ± | CD (0.05) | SEm ± | CD (0.05) |
| **Planting dates** | 0.0016 | 0.0055 | 0.0024 | 0.0083 | 0.0014 | 0.0043 |
| **Varieties** | 0.0017 | 0.0049 | 0.0015 | 0.0043 | 0.0011 | 0.0030 |
| **Planting dates x Varieties** | 0.0033 | 0.0095 | 0.0029 | 0.0083 | 0.0022 | 0.0061 |

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

The interaction effects of D x V were significant. The trend was similar during both the years. Planting of DMH-2 in October I fortnight recorded significantly higher grain weight (0.348 g grain$^{-1}$) over all other interaction effects.

4.1.6.6 Grains ear$^{-l}$ (cf. Table 13)

Grains ear$^{-l}$ differed significantly due to planting dates and varieties. During both the years DMH-1 recorded higher grains ear$^{-l}$ (461 and 487 grains during 1998-99 and 1999-2000 respectively). During 1998-99, DMH-1 recorded significantly higher grains ear$^{-1}$ followed by Prabha, DMH-2 and Deccan-103. During 1999-2000 DMH-1 (487 grains) and DMH-2 (486 grains) recorded on par grains ear$^{-l}$ and were significantly higher than other varieties. The trend in the mean values of two years was similar as that of 1998-99.

November II fortnight ($D_2$) planting recorded significantly higher grains ear$^{-1}$ over other planting dates. The trend was same during both the years. When averaged over two years, the grains ear$^{-l}$ increased significantly with every fortnight delay in planting from October I fortnight to November II fortnight (408, 430, 439 and 473 grains ear$^{-l}$ for October I fortnight ($D_1$), October II fortnight ($D_2$), November I fortnight ($D_3$) and November II fortnight ($D_4$) respectively).

The interaction effect of planting dates and varieties was significant during both the years. During 1998-99 significantly higher grains ear$^{-l}$ was recorded with November II fortnight planting with DMH-1 (501 grains ear$^{-1}$) interaction compared to others. During 1999-2000 $D_4$ x $V_2$ and $D_4$ x $V_3$ recorded on par grains ear$^{-1}$. (537 and 537 grains ear$^{-1}$) and was significantly higher over other interactions. In pooled data of two years, significantly higher grains ear$^{-1}$ (519 grains) recorded with $D_4$ x $V_2$ over other interactions.

4.1.6.7 Grain number m$^{-2}$ (cf. Table 14)

Planting dates and varieties caused significant difference in grain number m$^{-2}$ during both the seasons. Among the varieties, DMH-1 recorded significantly higher grain number m$^{-2}$ during 1998-99 and was on par with DMH-2 during 1999-2000. Average over the years significantly higher grain number m$^{-2}$ was registered for DMH-1 (2621 grains m$^{-2}$) over other varieties.

Delay in planting dates caused increase in grains number m$^{-2}$ during both the years. When averaged over the seasons, significantly higher grain number m$^{-2}$ was obtained in November II fortnight (2616 grains m$^{-2}$) over other planting dates. Next in the order was November I fortnight (2426 grains m$^{-2}$), October II fortnight (2370 grains m$^{-2}$) and the lower with October I fortnight (2257 grains m$^{-2}$).

During 1998-99 significantly higher grain number m$^{-2}$ was recorded with November II fortnight with DMH-1 (2770 grains m$^{-2}$)., While, during 1999-2000 November II fortnight with DMH-2 (2971 grains m$^{-2}$) and November II fortnight with DMH-1 (2969 grains m$^{-2}$) recorded on par, which were significantly higher than other interactions. When averaged over the years, DMH-1 with November- II fortnight recorded significantly higher grain number m$^{-2}$ (2870 grains), next in order were Prabha and DMH-2 planted in November II fortnight 2834 and 2761 grains m$^{-2}$ respectively) and Deccan-103 with November II fortnight (2730 grains m$^{-2}$). These were significantly higher than other interaction effects.

## 4.1.7 Water use (mm) and water use efficiency (kg ha$^{-1}$ mm$^{-1}$)

The water use by the maize crop and water use efficiency differed significantly due to planting dates and varieties.

4.1.7.1 Water use (mm) (cf. Table 15)

Water use by varieties varied significantly during both the years. The same trend was noticed during both the seasons. When averaged over the years, significantly higher water use (mm) was noticed in DMH-2 (551.84 mm) as compared to other varieties Prabha (534.84 mm), Deccan-103 (533.63 mm) and DMH-1 (533.33 mm) and these were statistically on par. However, Renuka recorded (353.80 mm) least water use.

Fortnightly delay in planting from October I fortnight to November II fortnight caused significant increase in water use of winter maize. When averaged over two years, significantly

## Table 13. Grains ear$^{-1}$ of maize varieties as influenced by planting dates

| Year | 1998-99 | | | | | 1999-2000 | | | | | Pooled | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| $V_1$ | 406 | 432 | 439 | 475 | **438** | 425 | 458 | 458 | 510 | **463** | 416 | 445 | 449 | 493 | **450** |
| $V_2$ | 426 | 455 | 462 | 501 | **461** | 447 | 481 | 482 | 537 | **487** | 437 | 468 | 472 | 519 | **474** |
| $V_3$ | 409 | 454 | 462 | 461 | **447** | 444 | 481 | 482 | 537 | **486** | 427 | 468 | 472 | 499 | **466** |
| $V_4$ | 421 | 449 | 456 | 494 | **455** | 441 | 474 | 476 | 530 | **480** | 431 | 462 | 466 | 512 | **468** |
| $V_5$ | 336 | 285 | 313 | 340 | **319** | 328 | 328 | 358 | 341 | **339** | 332 | 307 | 336 | 341 | **329** |
| **Mean** | **400** | **415** | **426** | **454** | **424** | **417** | **444** | **451** | **491** | **451** | **408** | **430** | **439** | **473** | **437** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Planting dates** | 0.56 | 1.95 | 0.63 | 2.17 | 0.42 | 1.30 |
| **Varieties** | 0.78 | 2.24 | 0.64 | 1.85 | 0.50 | 1.41 |
| **Planting dates x Varieties** | 1.55 | 4.48 | 1.28 | 3.71 | 1.01 | 2.82 |

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

## Table 14. Grain number $m^{-2}$ of maize varieties as infulenced by planting dates

| Year | 1998-99 | | | | | 1999-2000 | | | | | Pooled | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| $V_1$ | 2229 | 2389 | 2427 | 2631 | **2419** | 2353 | 2530 | 2533 | 2829 | **2561** | 2291 | 2460 | 2480 | 2730 | **2490** |
| $V_2$ | 2360 | 2514 | 2553 | 2770 | **2549** | 2471 | 2660 | 2667 | 2969 | **2692** | 2416 | 2587 | 2610 | 2870 | **2621** |
| $V_3$ | 2261 | 2512 | 2554 | 2550 | **2469** | 2454 | 2663 | 2668 | 2971 | **2689** | 2358 | 2588 | 2611 | 2761 | **2579** |
| $V_4$ | 2329 | 2407 | 2521 | 2735 | **2498** | 2439 | 2626 | 2627 | 2932 | **2656** | 2384 | 2517 | 2574 | 2834 | **2577** |
| $V_5$ | 1859 | 1580 | 1732 | 1884 | **1764** | 1815 | 1818 | 1981 | 1886 | **1875** | 1837 | 1699 | 1857 | 1885 | **1819** |
| **Mean** | **2208** | **2280** | **2357** | **2514** | **2340** | **2306** | **2459** | **2495** | **2717** | **2495** | **2257** | **2370** | **2426** | **2616** | **2417** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Planting dates** | 8.94 | 30.95 | 2.96 | 10.25 | 4.71 | 14.52 |
| **Varieties** | 9.19 | 26.54 | 3.15 | 9.09 | 4.86 | 13.60 |
| **Planting dates x Varieties** | 18.37 | 53.08 | 6.29 | 18.17 | 9.71 | 27.20 |

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

**Table 15. Water use (mm) of maize varieties as influenced by planting dates.**

| Year | 1998-99 | | | | | 1999-2000 | | | | | Pooled | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| $V_1$ | 490.96 | 519.59 | 528.79 | 549.99 | **522.33** | 519.59 | 535.15 | 557.40 | 567.60 | **544.94** | 505.28 | 527.37 | 543.10 | 558.80 | **533.63** |
| $V_2$ | 490.92 | 519.58 | 528.26 | 549.97 | **522.18** | 517.86 | 535.11 | 557.37 | 567.55 | **544.47** | 504.39 | 527.35 | 542.82 | 558.76 | **533.33** |
| $V_3$ | 503.82 | 538.12 | 549.53 | 558.25 | **537.43** | 531.74 | 559.70 | 584.65 | 588.88 | **566.24** | 517.78 | 548.91 | 567.09 | 573.57 | **551.84** |
| $V_4$ | 495.40 | 519.87 | 528.56 | 549.71 | **523.39** | 519.86 | 535.45 | 562.50 | 567.40 | **546.30** | 507.63 | 527.66 | 545.53 | 558.56 | **534.84** |
| $V_5$ | 336.29 | 353.98 | 337.73 | 378.44 | **351.61** | 330.67 | 352.63 | 374.90 | 365.76 | **355.99** | 333.48 | 353.31 | 356.32 | 372.10 | **353.80** |
| **Mean** | **463.48** | **490.23** | **494.57** | **517.27** | **491.39** | **483.94** | **503.61** | **527.36** | **531.44** | **511.59** | **473.71** | **496.92** | **510.97** | **524.36** | **501.49** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Planting dates** | 0.232 | 0.803 | 0.291 | 1.008 | 0.186 | 0.574 |
| **Varieties** | 0.414 | 1.195 | 0.304 | 1.455 | 0.326 | 0.913 |
| **Planting dates x Varieties** | 0.828 | 2.391 | 1.007 | 2.909 | 0.652 | 1.825 |

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

The interaction effects (DxV) were significant and showed similar trend during both the years. When averaged over the years, significantly higher water use of 573.57 mm was recorded for November II fortnight with DMH-2 ($D_4xV_3$), while lower of 333.48 mm in October I fortnight with Renuka ($D_1XV_5$).

**4.1.7.2 Water use efficiency (kg ha$^{-1}$ mm$^{-1}$) (cf. Table 16)**

Varieties differed significantly with respect to water use efficiency during both the years. When averaged over two years, significantly higher WUE was recorded for DMH-2 (14.87 kg ha$^{-1}$ mm$^{-1}$), next in order were DMH-I (14.11 kg ha$^{-1}$ mm$^{-1}$), Deccan-103 (12.54 kg ha$^{-1}$ mm$^{-1}$), Prabha (11.80 kg ha$^{-1}$ mm$^{-l}$), and significantly lower with Renuka (10.45 kg ha$^{-1}$ mm$^{-1}$).

Water use efficiency differed significantly with planting dates during both the years. Delay in fortnightly planting significantly lowered the water use efficiency. When averaged over the years, higher WUE was recorded with October I fortnight (13.91 kg ha$^{-1}$ mm$^{-1}$), while the lower for November II $^{\text{fortnight}}$ (11.85 kg ha$^{-1}$ mm$^{-1}$).

Interaction effect of DxV caused significant differences in WUE during both the years. Average over the years, higher water use efficiency was recorded for October I fortnight with DMH-2 (15.94 kg ha$^{-1}$ mm$^{-1}$) as compared to other interactions.

**4.1.9 Correlation studies (cr. Table 17)**

Highly significant correlation was observed between grain yield and LAI at anthesis(r=0.89) and at physiological maturity (r=0.89), total dry matter plant$^{-1}$ at anthesis (r=0.88) and at physiological maturity (r=0.83), days to 50% flowering (r=0.86) and physiological maturity (r=0.92), grain weight (r=0.95), grains ear$^{-1}$ (r=0.92), grain number m$^{-2}$ (r=0.92) water use (r=0.93) and water use efficiency (r=0.93).

**4.1.9 Economics (cr. Table 18 and Appendix 21)**

The planting dates and varieties influenced cost of production, gross return, net return and B: C ratio of maize crop. The higher cost of production was recorded in DMH-2 (Rs. 14406 ha$^{-1}$), followed by DMH-I (Rs. 14133 ha$^{-1}$) and Deccan-I03 (Rs. 13801 ha$^{-1}$), similarly the gross return (Rs. 43236 ha$^{-1}$), net return (Rs. 28830 ha$^{-1}$) and B: C ratio (3.00) were also higher in DMH-2 followed by DMH-I (Rs. 39895 ha$^{-1}$, Rs. 25762 ha$^{-1}$, Rs. 2.82 respectively) and Deccan-I03 (Rs. 35745 ha$^{-1}$, Rs. 21944 ha$^{-1}$, Rs. 2.59 respectively). Among the planting dates the higher cost of production (Rs. 13791 ha$^{-1}$), gross return (Rs. 35469 ha$^{-1}$), net return (Rs. 21678 ha$^{-1}$) and B: C ratio (2.55) were noticed in October I fortnight ($D_1$) as compared to others. The interaction was also shown differences, however the highest gross return (Rs. 45015 ha$^{-1}$), net return (Rs 30464 ha$^{-1}$) and B: C ratio (3.09) were recorded for October II fortnight planting with DMH-2.

# 4.2 EFFECT OF IRRIGATION SCHEDULING, PLANT DENSITY AND NITROGEN LEVELS ON GROWTH AND YIELD OF MAIZE

## 4.2.1 Plant height (cm) (cf. Table 19, Appendix 10 and Appendix 11)

Plant height differed significantly due to irrigation scheduling, plant density and nitrogen levels at all the growth stages. The plant height increased as the crop growth progressed, the magnitude of increase was nearly seven times between 30 DAS and 90 DAS, but stagnant towards physiological maturity.

Scheduling irrigation at higher IW /CPE ratio increased the plant height significantly at 30, 60, 90 DAS and at physiological maturity during both the seasons. When averaged over the years, at all the growth stages significantly higher plant height was recorded in $I_3$ (1.2 IW /CPE ratio), followed by $I_2$ (0.9 IW /CPE ratio) and $I_1$ (0.6 IW /CPE ratio).

At 30, 60, 90 DAS and at physiological maturity plant height increased significantly with increase in plant density during both the years. Significantly higher plant height was recorded from $P_3$ (111111 plants ha$^{-1}$) as compared to $P_2$ (83333 plants ha$^{-l}$) and $P_1$ (55555 plants ha$^{-l}$).

Similarly, plant height increased significantly with increase in nitrogen levels at 30, 60, 90 DAS and at physiological maturity during both the seasons. Significantly higher plant

**Table 16. Water use efficiency (kg ha$^{-1}$ mm$^{-1}$) of maize varieties as influenced by planting dates**

| Year | 1998-99 | | | | | 1999-2000 | | | | | Pooled | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| $V_1$ | 13.51 | 12.57 | 11.60 | 11.11 | **12.20** | 13.49 | 13.24 | 12.42 | 12.33 | **12.87** | 13.50 | 12.91 | 12.02 | 11.73 | **12.54** |
| $V_2$ | 15.34 | 14.48 | 12.72 | 12.66 | **13.80** | 15.06 | 14.75 | 13.83 | 13.97 | **14.40** | 15.20 | 14.62 | 13.29 | 13.33 | **14.11** |
| $V_3$ | 16.11 | 15.46 | 13.76 | 13.24 | **14.64** | 15.79 | 15.70 | 14.48 | 14.42 | **15.10** | 15.94 | 15.58 | 14.13 | 13.84 | **14.87** |
| $V_4$ | 12.98 | 12.15 | 10.99 | 10.56 | **11.67** | 12.45 | 12.20 | 11.36 | 11.70 | **11.93** | 12.71 | 12.17 | 11.18 | 11.14 | **11.80** |
| $V_5$ | 12.30 | 9.85 | 10.11 | 8.85 | **10.28** | 12.11 | 10.83 | 9.93 | 9.62 | **10.62** | 12.21 | 10.34 | 10.02 | 9.22 | **10.45** |
| **Mean** | **14.05** | **12.90** | **11.84** | **11.28** | **12.52** | **13.78** | **13.34** | **12.40** | **12.41** | **12.98** | **13.91** | **13.13** | **12.13** | **11.85** | **12.75** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Planting dates** | 0.052 | 0.181 | 0.071 | 0.245 | 0.026 | 0.081 |
| **Varieties** | 0.058 | 0.164 | 0.055 | 0.155 | 0.029 | 0.080 |
| **Planting dates x Varieties** | 0.116 | 0.327 | 0.109 | 0.309 | 0.038 | 0.161 |

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

**Table 17. Correlation co-efficient between various characters and grain yield as influenced by maize varieties and planting dates**

| Sl.No. | Characters | Correlation co-efficient |
|---|---|---|
| 1. | Plant height at 30 DAS (cm) | 0.41 |
| 2. | Plant height at anthesis (cm) | 0.54 |
| 3. | No. of leaves at 30 DAS | -0.79* |
| 4. | No. of leaves at anthesis | 0.89** |
| 5. | Leaf area index at 30 DAS | -0.85** |
| 6. | LAI at Anthesis | 0.89** |
| 7. | LAI at physiological maturity | 0.89** |
| 8. | TDM at 30 DAS | -0.80* |
| 9. | TDM at Anthesis | 0.88** |
| 10. | TDM at physiological maturity | 0.83** |
| 11. | Days to 50% flowering | 0.86** |
| 12. | Days to physiological maturity | 0.92** |
| 13. | Grain weight | 0.95** |
| 14. | Grains $ear^{-1}$ | 0.92** |
| 15. | Grain number $m^{-2}$ | 0.92** |
| 16. | Water use | 0.93** |
| 17. | Water use efficiency | 0.95** |

**- Significant at 0.01 levels of probability
* - Significant at 0.05 levels of probability
TDM: Total dry matter
DAS: Days after sowing

## Table 18. Economics of maize varieties as influenced by planting dates (Pooled data of Two years)

| Treatments | Cost of production @ Rs. $ha^{-1}$ | | | | | Gross return @ Rs. $ha^{-1}$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | D1 | D2 | D3 | D4 | **Mean** | D1 | D2 | D3 | D4 | **Mean** |
| V1 | 13858 | 13854 | 13741 | 13751 | **13801** | 36515 | 36349 | 35016 | 35099 | **35745** |
| V2 | 14196 | 14213 | 14015 | 14108 | **14133** | 40730 | 40857 | 38444 | 39549 | **39895** |
| V3 | 14432 | 14551 | 14335 | 14306 | **14406** | 43577 | 45015 | 42422 | 41928 | **43236** |
| V4 | 13710 | 13699 | 13570 | 13619 | **13650** | 34662 | 34419 | 32879 | 33443 | **33851** |
| V5 | 12758 | 12591 | 12558 | 12503 | **12603** | 21862 | 19670 | 19294 | 18525 | **19838** |
| **Mean** | **13791** | **13782** | **13644** | **13657** | **13718** | **35469** | **35262** | **33611** | **33709** | **34513** |
| Treatments | Net return @ Rs. $ha^{-1}$ | | | | | Benefit cost ratio | | | | |
| | D1 | D2 | D3 | D4 | **Mean** | D1 | D2 | D3 | D4 | **Mean** |
| V1 | 22656 | 22495 | 21275 | 21348 | **21944** | 2.63 | 2.62 | 2.55 | 2.55 | **2.59** |
| V2 | 26535 | 26644 | 24428 | 25441 | **25762** | 2.87 | 2.87 | 2.74 | 2.80 | **2.82** |
| V3 | 29145 | 30464 | 28087 | 27622 | **28830** | 3.02 | 3.09 | 2.96 | 2.93 | **3.00** |
| V4 | 20951 | 20719 | 19309 | 19824 | **20201** | 2.53 | 2.51 | 2.42 | 2.46 | **2.48** |
| V5 | 9104 | 7078 | 6736 | 6022 | **7235** | 1.71 | 1.56 | 1.54 | 1.48 | **1.57** |
| **Mean** | **21678** | **21480** | **19967** | **20051** | **20794** | **2.55** | **2.53** | **2.44** | **2.44** | **2.49** |

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

**Table 19. Plant height (cm) of maize at different growth stages as influenced by irrigation scheduling, plant density and nitrogen levels (pooled data of two years)**

| Growth stages | 30 DAS | | | | 60 DAS | | | | 90 DAS | | | | Physiological maturity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 27.87 | 29.72 | 30.57 | **29.39** | 143.00 | 153.47 | 159.84 | **152.10** | 198.00 | 208.33 | 213.83 | **206.72** | 198.00 | 208.33 | 213.83 | **206.72** |
| $I_1N_2$ | 27.99 | 29.81 | 30.69 | **29.50** | 148.00 | 159.15 | 164.67 | **157.27** | 203.00 | 214.00 | 219.67 | **212.22** | 203.00 | 214.00 | 219.67 | **212.22** |
| $I_1N_3$ | 27.99 | 29.82 | 30.62 | **29.47** | 151.50 | 163.00 | 166.50 | **160.33** | 206.50 | 218.00 | 221.50 | **215.33** | 206.50 | 218.00 | 221.50 | **215.33** |
| $I_1N_4$ | 27.99 | 29.79 | 30.60 | **29.46** | 157.42 | 162.84 | 166.84 | **162.36** | 207.42 | 217.83 | 221.67 | **215.64** | 207.42 | 217.83 | 221.67 | **215.64** |
| **Mean** | **27.96** | **29.78** | **30.62** | **29.45** | **149.98** | **159.61** | **164.46** | **158.02** | **203.73** | **214.54** | **219.17** | **212.48** | **203.73** | **214.54** | **219.17** | **212.48** |
| $I_2N_1$ | 28.57 | 32.18 | 33.05 | **31.27** | 148.17 | 155.83 | 159.69 | **154.56** | 203.27 | 210.67 | 214.68 | **209.54** | 203.27 | 210.67 | 214.68 | **209.54** |
| $I_2N_2$ | 29.84 | 33.08 | 34.14 | **32.35** | 157.00 | 163.34 | 167.17 | **162.50** | 212.05 | 218.33 | 222.17 | **217.52** | 212.05 | 218.33 | 222.17 | **217.52** |
| $I_2N_3$ | 30.32 | 33.55 | 35.52 | **33.13** | 161.84 | 167.17 | 171.00 | **166.67** | 216.88 | 222.17 | 226.00 | **221.68** | 216.88 | 222.17 | 226.00 | **221.68** |
| $I_2N_4$ | 30.37 | 33.80 | 35.78 | **33.32** | 162.83 | 169.42 | 173.00 | **168.42** | 217.77 | 224.42 | 228.00 | **223.40** | 217.77 | 224.42 | 228.00 | **223.40** |
| **Mean** | **29.77** | **33.15** | **34.62** | **32.52** | **157.46** | **163.94** | **167.71** | **163.04** | **212.49** | **218.90** | **222.71** | **218.03** | **212.49** | **218.90** | **222.71** | **218.03** |
| $I_3N_1$ | 28.89 | 33.12 | 33.02 | **31.67** | 150.00 | 157.33 | 159.34 | **155.56** | 205.00 | 212.33 | 214.33 | **210.55** | 205.00 | 212.33 | 214.33 | **210.55** |
| $I_3N_2$ | 30.39 | 34.15 | 34.50 | **33.01** | 159.34 | 165.00 | 165.17 | **163.17** | 214.50 | 220.00 | 223.17 | **219.22** | 214.50 | 220.00 | 223.17 | **219.22** |
| $I_3N_3$ | 31.19 | 34.89 | 35.62 | **33.90** | 162.15 | 168.84 | 172.17 | **167.72** | 217.23 | 224.00 | 227.17 | **222.80** | 217.23 | 224.00 | 227.17 | **222.80** |
| $I_3N_4$ | 31.80 | 35.20 | 36.07 | **34.36** | 163.67 | 170.84 | 173.67 | **169.39** | 218.70 | 225.83 | 228.80 | **224.44** | 218.70 | 225.83 | 228.80 | **224.44** |
| **Mean** | **30.56** | **34.34** | **34.80** | **33.23** | **158.79** | **165.50** | **167.58** | **163.96** | **213.86** | **220.54** | **223.37** | **219.26** | **213.86** | **220.54** | **223.37** | **219.26** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 28.44 | 31.67 | 32.21 | **30.78** | 147.06 | 155.54 | 159.62 | **154.07** | 202.09 | 210.44 | **214.28** | 208.94 | 202.09 | 210.44 | 214.28 | **208.94** |
| **N2** | 29.40 | 32.35 | 33.11 | **31.62** | 154.78 | 162.50 | 165.67 | **160.98** | 209.85 | 217.44 | **221.67** | 216.32 | 209.85 | 217.44 | 221.67 | **216.32** |
| **N3** | 29.83 | 32.75 | 33.92 | **32.17** | 158.50 | 166.33 | 169.89 | **164.91** | 213.54 | 221.39 | **224.89** | 219.94 | 213.54 | 221.39 | 224.89 | **219.94** |
| **N4** | 30.05 | 32.93 | 34.15 | **32.38** | 161.30 | 167.70 | 171.17 | **166.72** | 214.63 | 222.69 | **226.16** | 221.16 | 214.63 | 222.69 | 226.16 | **221.16** |
| **Mean** | **29.43** | **32.43** | **33.35** | **31.73** | **155.41** | **163.02** | **166.58** | **161.67** | **210.03** | **217.99** | **221.75** | **216.59** | **210.03** | **217.99** | **221.75** | **216.59** |

| | 30 DAS | | 60 DAS | | 90 DAS | | Physiological maturity | |
|---|---|---|---|---|---|---|---|---|
| **Comparing Means of** | SEm ± | CD (0.05) | SEm ± | CD (0.05) | SEm ± | CD (0.05) | SEm ± | CD (0.05) |
| **Irrigation (I)** | 0.112 | 0.365 | 0.074 | 0.242 | 0.065 | 0.212 | 0.065 | 0.212 |
| **Plant Density (P)** | 0.082 | 0.238 | 0.115 | 0.335 | 0.104 | 0.304 | 0.104 | 0.304 |
| **Nitrogen levels (N)** | 0.041 | 0.112 | 0.106 | 0.294 | 0.180 | 0.526 | 0.180 | 0.526 |
| **I X P** | 0.141 | 0.412 | 0.198 | 0.579 | 0.084 | 0.233 | 0.084 | 0.233 |
| **I X N** | 0.070 | 0.195 | 0.184 | 0.509 | 0.146 | 0.404 | 0.146 | 0.404 |
| **P X N** | 0.070 | 0.195 | 0.184 | 0.509 | 0.146 | 0.404 | 0.146 | 0.404 |
| **I X P X N** | 0.122 | 0.337 | 0.318 | 0.884 | 0.252 | 0.699 | 0.252 | 0.699 |

DAS: Days after sowing

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density (P) : $P_1$ = 55555 Plants $ha^{-1}$; $P_2$ = 83333 Plants $ha^{-1}$; $P_3$ = 111111 Plants $ha^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg $ha^{-1}$; $N_2$ = 150 Kg $ha^{-1}$; $N_3$ = 225 Kg $ha^{-1}$; $N_4$ = 300 Kg $ha^{-1}$

Table 20. Leaf area index of maize at different growth stages as influenced by irrigation scheduling, plant density and nitrogen levels (pooled data of two years)

| Growth stages | 30 DAS | | | | 60 DAS | | | | 90 DAS | | | | 120 DAS | | | | Physiological maturity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 0.62 | 0.90 | 1.12 | **0.88** | 2.73 | 3.01 | 3.69 | **3.14** | 2.52 | 3.29 | 3.50 | **3.10** | 1.71 | 2.18 | 2.53 | **2.14** | 1.24 | 1.58 | 1.80 | **1.54** |
| $I_1N_2$ | 0.62 | 0.90 | 1.09 | **0.87** | 2.70 | 3.48 | 3.92 | **3.37** | 2.68 | 3.30 | 3.66 | **3.21** | 1.72 | 2.25 | 2.65 | **2.20** | 1.41 | 1.64 | 1.92 | **1.65** |
| $I_1N_3$ | 0.63 | 0.91 | 1.10 | **0.88** | 2.78 | 3.41 | 3.84 | **3.34** | 2.62 | 3.00 | 3.41 | **3.01** | 1.72 | 2.12 | 2.39 | **2.08** | 1.24 | 1.61 | 1.82 | **1.56** |
| $I_1N_4$ | 0.63 | 0.91 | 1.10 | **0.88** | 2.76 | 3.37 | 3.80 | **3.31** | 2.60 | 2.95 | 3.22 | **2.92** | 1.72 | 2.11 | 2.34 | **2.05** | 1.19 | 1.60 | 1.79 | **1.53** |
| **Mean** | **0.62** | **0.90** | **1.10** | **0.88** | **2.74** | **3.32** | **3.81** | **3.29** | **2.60** | **3.13** | **3.44** | **3.06** | **1.72** | **2.16** | **2.48** | **2.12** | **1.27** | **1.61** | **1.83** | **1.57** |
| $I_2N_1$ | 0.62 | 0.91 | 1.12 | **0.88** | 2.95 | 3.91 | 4.41 | **3.76** | 2.89 | 3.85 | 4.21 | **3.65** | 1.82 | 2.44 | 2.89 | **2.38** | 1.33 | 1.74 | 2.11 | **1.73** |
| $I_2N_2$ | 0.63 | 0.91 | 1.11 | **0.88** | 2.99 | 4.06 | 4.66 | **3.90** | 2.97 | 4.10 | 4.35 | **3.81** | 1.88 | 2.69 | 3.13 | **2.56** | 1.35 | 1.88 | 2.28 | **1.83** |
| $I_2N_3$ | 0.63 | 0.91 | 1.11 | **0.88** | 3.00 | 4.11 | 4.71 | **3.94** | 2.99 | 4.14 | 4.41 | **3.85** | 1.89 | 2.63 | 3.17 | **2.56** | 1.36 | 1.93 | 2.35 | **1.88** |
| $I_2N_4$ | 0.63 | 0.91 | 1.11 | **0.88** | 3.00 | 4.12 | 4.71 | **3.94** | 2.99 | 4.15 | 4.43 | **3.86** | 1.89 | 2.65 | 3.18 | **2.57** | 1.37 | 1.94 | 2.35 | **1.88** |
| **Mean** | **0.63** | **0.91** | **1.11** | **0.88** | **2.99** | **4.05** | **4.62** | **3.88** | **2.96** | **4.06** | **4.35** | **3.79** | **1.87** | **2.60** | **3.09** | **2.52** | **1.35** | **1.87** | **2.27** | **1.83** |
| $I_3N_1$ | 0.62 | 0.92 | 1.12 | **0.89** | 2.95 | 4.07 | 4.50 | **3.84** | 2.90 | 3.97 | 4.24 | **3.70** | 1.83 | 2.50 | 3.02 | **2.45** | 1.33 | 1.78 | 2.18 | **1.76** |
| $I_3N_2$ | 0.63 | 0.93 | 1.11 | **0.89** | 3.01 | 4.24 | 4.93 | **4.06** | 2.99 | 4.19 | 4.39 | **3.85** | 1.89 | 2.69 | 3.30 | **2.63** | 1.38 | 1.95 | 2.39 | **1.90** |
| $I_3N_3$ | 0.63 | 0.91 | 1.10 | **0.88** | 3.33 | 4.29 | 4.99 | **4.20** | 3.00 | 4.24 | 4.44 | **3.89** | 1.90 | 2.73 | 3.36 | **2.66** | 1.38 | 2.09 | 2.46 | **1.98** |
| $I_3N_4$ | 0.63 | 0.91 | 1.10 | **0.88** | 3.02 | 4.30 | 5.00 | **4.11** | 3.00 | 4.25 | 4.45 | **3.90** | 1.90 | 2.74 | 3.38 | **2.67** | 1.39 | 2.10 | 2.47 | **1.98** |
| **Mean** | **0.63** | **0.92** | **1.11** | **0.88** | **3.08** | **4.22** | **4.85** | **4.05** | **2.97** | **4.16** | **4.38** | **3.84** | **1.88** | **2.67** | **3.26** | **2.60** | **1.37** | **1.98** | **2.37** | **1.90** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 0.62 | 0.91 | 1.12 | **0.88** | 2.88 | 3.66 | 4.20 | **3.58** | 2.77 | 3.70 | 3.98 | **3.48** | 1.78 | 2.37 | 2.81 | **2.32** | 1.30 | 1.70 | 2.03 | **1.67** |
| **N2** | 0.63 | 0.91 | 1.10 | **0.88** | 2.90 | 3.93 | 4.50 | **3.78** | 2.88 | 3.86 | 4.13 | **3.62** | 1.83 | 2.54 | 3.03 | **2.46** | 1.38 | 1.82 | 2.19 | **1.80** |
| **N3** | 0.63 | 0.91 | 1.10 | **0.88** | 3.04 | 3.94 | 4.51 | **3.83** | 2.87 | 3.79 | 4.09 | **3.58** | 1.84 | 2.49 | 2.97 | **2.43** | 1.33 | 1.87 | 2.21 | **1.80** |
| **N4** | 0.63 | 0.91 | 1.10 | **0.88** | 2.93 | 3.93 | 4.50 | **3.79** | 2.86 | 3.78 | 4.03 | **3.56** | 1.84 | 2.50 | 2.96 | **2.43** | 1.31 | 1.88 | 2.20 | **1.80** |
| **Mean** | **0.63** | **0.91** | **1.11** | **0.88** | **2.93** | **3.86** | **4.43** | **3.74** | **2.84** | **3.78** | **4.06** | **3.56** | **1.82** | **2.48** | **2.94** | **2.41** | **1.33** | **1.82** | **2.16** | **1.77** |
| | **30 DAS** | | | | **60 DAS** | | | | **90 DAS** | | | | **120 DAS** | | | | **Physiological maturity** | | | |
| **Comparing Means of** | **SEm ±** | | **CD ( 0.05)** | | **SEm ±** | | **CD ( 0.05)** | | **SEm ±** | | **CD ( 0.05)** | | **SEm ±** | | **CD ( 0.05)** | | **SEm ±** | | **CD ( 0.05)** | |
| **Irrigation (I)** | 0.001 | | 0.004 | | 0.012 | | 0.040 | | 0.029 | | 0.094 | | 0.002 | | 0.006 | | 0.009 | | 0.029 | |
| **Plant Density (P)** | 0.002 | | 0.007 | | 0.013 | | 0.039 | | 0.030 | | 0.086 | | 0.003 | | 0.008 | | 0.012 | | 0.034 | |
| **Nitrogen levels (N)** | 0.002 | | 0.004 | | 0.015 | | 0.041 | | 0.034 | | 0.094 | | 0.002 | | 0.006 | | 0.013 | | 0.037 | |
| **I X P** | 0.004 | | 0.011 | | 0.023 | | 0.068 | | 0.051 | | 0.149 | | 0.005 | | 0.014 | | 0.020 | | 0.059 | |
| **I X N** | 0.003 | | 0.008 | | 0.025 | | 0.070 | | 0.059 | | 0.164 | | 0.004 | | 0.010 | | 0.023 | | 0.064 | |
| **P X N** | 0.003 | | 0.008 | | 0.025 | | 0.070 | | 0.059 | | 0.164 | | 0.004 | | 0.010 | | 0.023 | | 0.064 | |
| **I X P X N** | 0.005 | | 0.013 | | 0.044 | | 0.121 | | 0.102 | | 0.283 | | 0.006 | | 0.018 | | 0.040 | | 0.011 | |

DAS: Days after sowing

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$;$N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$;$N_4$ = 300 Kg ha$^{-1}$

The interaction effect between irrigation scheduling and plant density (IxP) was significant at 30, 60, 90 DAS and at physiological maturity during both the years. Increase in irrigation scheduling coupled with increase in plant density recorded significant increase in plant height. When averaged over the years, significantly higher plant height was recorded at $I_3$ (1.2 IW / CPE ratio) with $P_3$ (111111 plants $ha^{-l}$) than other interaction effects.

Irrigation scheduling and nitrogen level interaction effects differed significantly at 30, 60, 90 DAS and at physiological maturity during both the years. Increase in irrigation level and nitrogen level caused significant increase in plant height. When averaged over the years, at all the growth stages significantly higher plant height was registered in irrigation scheduling at $I_3$ (1.2 IW/CPE ratio) accompanied with nitrogen level of $N_4$ (300 kg $ha^{-l}$) as compared to other interaction effects.

The interaction effect of plant density and nitrogen level had significant influence on plant height at 30, 60, 90 DAS and at physiological maturity during both the years. Increase in plant density along with increase in nitrogen level significantly increased the plant height. Significantly higher plant height was noticed in plant density at $P_3$ (111111 plants $ha^{-l}$) with nitrogen level of $N_4$ (300 kg $ha^{-l}$) as compared to other interaction effects.

The interaction effects between irrigation scheduling, plant density and nitrogen levels (IxPxN) were significant at all the growth stages during both the years. Increase in irrigation level from $I_1$ (0.6 IW/CPE ratio) to $I_3$ (1.2 IW/CPE ratio) accompanied with increase in plant density from $P_1$ (55555 plants $ha^{-l}$) to $P_3$ (111111 plants $ha^{-l}$) and nitrogen level from $N_l$ (75 kg $ha^{-l}$) to $N_4$ (300 kg $ha^{-l}$) significantly increased the plant height at 30, 60, 90 and at physiological maturity. Significantly higher plant height was recorded for irrigation scheduling at $I_3$ (1.2 IW / CPE ratio) coupled with plant density of $P_3$ (111111 plants $ha^{-l}$) and nitrogen level of $N_4$ (300 kg $ha^{-l}$) over other interaction effects.

### 4.2.2 Leaf area index (LAI) (cf. Table 20; Appendix 12 and Appendix 13)

Leaf area index differed significantly due to effect of irrigation scheduling, plant density and nitrogen levels at 30, 60, 90, 120 DAS and at physiological maturity during both the years. LAI progressively increased from 30 DAS to 60 DAS, further increase was marginal and shown declining trend at 90 DAS and decreased drastically towards physiological maturity.

The leaf area index was significant at 60, 90, 120 DAS and at physiological maturity except at 30 DAS during both the years. Increase in the level of irrigation from $I_1$ to $I_3$ caused significant increase in LAI recording maximum at $I_3$ (1.2 IW/CPE ratio) as compared to other two irrigation levels.

Increased plant density from $P_1$ to $P_3$ recorded significantly higher LAI. Plant density of $P_3$ (111111 plants $ha^{-l}$) recorded significantly higher LAI as compared to $P_2$ and $P_1$ at 30, 60, 90, 120 DAS and at physiological maturity during both the years.

The LAI was not significant due to nitrogen levels at 30 DAS during both the seasons but, differed significantly at 60, 90, 120 DAS and at physiological maturity. At 60 DAS significantly higher LAI recorded at $N_3$ (225 kg $ha^{-l}$). At 90 120 DAS and physiological maturity. At 60 DAS significantly higher LAI recorded at $N_3$ (225 kg $ha^{-l}$). At 90 & 120 DAS and physiological maturity significantly higher LAI recorded at $N_2$ and which was on par with $N_3$ (225 kg $ha^{-l}$) and $N_4$ (300 kg $ha^{-l}$).

The interaction between irrigation scheduling and plant density at 30 DAS recorded significant difference only for scheduling irrigation for different levels of plant density, but not for irrigation scheduling at same level of plant density. However, significant differences were observed at 60, 90, 120 and at physiological maturity during both the years. The treatment combination of $I_3$ x $P_3$ recorded higher LAI over other interaction effects.

The interaction effects due to irrigation scheduling and nitrogen levels were not significant at 30 DAS during both the years, while significant at 60, 90, 120 and at physiological maturity. When averaged over the years, at 60, 90, 120 DAS and at physiological maturity the LAI was increased from $N_l$ (75 kg $ha^{-l}$) to $N_2$ (150 kg $ha^{-l}$) at $I_1$ irrigation scheduling, from $N_1$ (75 kg $ha^{-l}$) to $N_3$ (225kg $ha^{-l}$) at $I_2$ and $I_3$ irrigation schedulings. The increase in LAI was significant in former and in latter it was significant from $N_1$ to $N_2$ and statistically comparable for $N_2$ to $N_3$ respectively.

The interaction effect due to plant density and nitrogen level differed significantly in LAI during both the years at all the growth stages. The LAI increased with increase in plant density and nitrogen dose. The increase was significant for increase in plant density at same level of nitrogen. The increase in nitrogen dose at $P_1$ was not significant, but significant at $P_2$ and $P_3$ between $N_1$ and $N_2$ and on par for $N_2$ to $N_4$.

The interaction between irrigation scheduling, plant density and nitrogen levels differed in LAI during both the years. At 30 DAS, the LAI was not significant between different levels of irrigation coupled with nitrogen levels at same level of plant density. However, LAI was significant at different levels of plant density. While at 60, 90, 120 DAS and at physiological maturity LAI was significant. Higher LAI was recorded at $I_3$ irrigation scheduling coupled with $P_3$ plant density and $N_2$ nitrogen level as compared to other interaction effects. But, this was statistically on par with $I_3$ x $P_3$ X $N_3$ and $I_3$ x $P_3$ X $N_4$ interaction effects.

### 4.2.3 Dry matter (g plant$^{-1}$) and its partitioning to different plant parts

4.2.3.1 Leaf dry matter (g plant$^{-1}$) (cf. Table 21; Appendix 15 and Appendix 16)

Leaf dry matter (g plant$^{-l}$) differed significantly due to irrigation scheduling, plant density and nitrogen levels at 30, 60, 90, 120 DAS and at physiological maturity during both the years. The leaf dry matter increased from 30 DAS to 60 DAS, and from 90 DAS to physiological maturity decreased marginally.

Leaf dry matter plant$^{-l}$ differed significantly due to irrigation scheduling at 30, 60, 90, 120 DAS and at physiological maturity during both the years. Increase in irrigation level from $I_1$ to $I_2$ at 30 DAS and from $I_1$ to $I_3$ at 60, 90, 120 DAS and physiological maturity recorded significantly higher leaf dry matter plant$^{-1}$.

The leaf dry matter plant$^{-l}$ significantly decreased with increase in plant density from $P_l$ to $P_3$ at all the growth stages during both the years. Significantly higher leaf dry matter plant$^{-1}$ was recorded in $P_1$ over others.

Increase in nitrogen level from $N_1$ to $N_3$ significantly increased the leaf dry matter plant$^{-l}$ at all the growth stages except at 30 DAS during both the years. Significantly higher leaf dry matter plant$^{-l}$ was registered! for $N_3$ over other levels. At 30 DAS, the leaf dry matter plant$^{-1}$ due to nitrogen level was not significant.

The interaction effect of irrigation scheduling and plant density differed significantly at all the growth stages except at 30 DAS during both the years. At 30 DAS the interaction effect at different levels of irrigation scheduling with same level of plant density was not significant, however at same level of irrigation with different levels of plant density the leaf dry matter plant$^{-1}$ was significant. Significantly higher leaf dry matter plant$^{-1}$ was recorded for $I_3$ x $P_1$ at 60 and 90 DAS and for $I_2$ x $P_1$ at 120 DAS and at physiological maturity over other interaction during respective growth stages.

The irrigation scheduling and nitrogen level interaction effects were significant at 60, 90, 120 DAS and at physiological maturity except at 30 DAS during both the years. The leaf dry matter plant$^{-1}$ at 30 DAS was not significant. At other growth stages significantly higher leaf dry matter plant$^{-1}$ was obtained due to $I_3$ x $N_3$ interaction compared to others. However, $I_3$ x $N_3$ and $I_3$ x $N_4$ interactions recorded on par leaf dry matter plant $^{-1}$.

The interaction effect due to plant density and nitrogen level was significant at all the growth stages except at 30 DAS during both the seasons. At 60, 90, 120 DAS and at physiological maturity normal plant density ($P_l$) with increase in nitrogen levels from $N_1$ to $N_2$ recorded significant increase in leaf dry matter (g plant$^{-1}$) whereas, at high ($P_2$) and very high ($P_3$) plant densities increase in nitrogen from $N_1$ to $N_3$ significantly increase the leaf dry matter plant$^{-1}$. Significantly higher leaf dry matter plant$^{-l}$ was recorded at $P_l$ (55555 plants ha$^{-l}$) plant density with $N_3$ (225 kg ha$^{-l}$) nitrogen level. This interaction was statistically at par with $P_l$ x $N_4$.

The interaction effect of irrigation scheduling, plant density and nitrogen level (IxPxN) was significant during all the growth stages. Significantly higher leaf dry matter plant$^{-l}$ was recorded for $I_3$ x $P_l$ x $N_4$ at 60 DAS, $I_2$ x $P_l$ X $N_3$ at 90, 120 DAS and at physiological maturity, however $I_3$ x $P_l$ X $N_3$ and $I_3$ x $P_l$ X $N_1$ recorded on par leaf dry matter plant$^{-1}$.

4.2.3.2 Stem dry matter (g $plant^{-1}$) (cf. Table 22; Appendix 16 and Appendix 17)

Stem dry matter $plant^{-l}$ differed significantly due to irrigation scheduling, plant density and nitrogen levels at all the growth stages except at 30 DAS during both the years. The stem dry matter $plant^{-l}$ increased rapidly from 30 DAS to 90 DAS, marginally increased from 90 DAS upto 120 DAS, and marginally declined towards physiological maturity.

The stem dry matter $plant^{-l}$ was non-significant at 30 DAS, while significant at other growth stages due to irrigation scheduling during both the years. At 60, 90, 120 DAS and at physiological maturity increase in the level of irrigation from $I_1$ and $I_2$ significantly increased the stem dry matter $plant^{-1}$. Significantly higher stem dry matter $plant^{-l}$ was recorded at $I_3$ over $I_1$, but $I_3$ and $I_2$ recorded on par stem dry matter $plant^{-1}$.

Increase in the plant density from 55555 ($P_1$) to 111111 ($P_3$) through 83, 333 ($P_1$) plants $ha^{-1}$ significantly reduced the stem dry matter $plant^{-1}$ at all the growth stages except 30 DAS during both the years. Significantly higher stem dry matter $plant^{-1}$ was recorded at 55555 plants $ha^{-1}$ over other plant densities.

The stem dry matter $plant^{-1}$ significantly increased due to increase in the nitrogen level from $N_1$ (75 kg $ha^{-1}$) to $N_3$ (225 kg $ha^{-1}$). The stem dry matter $plant^{-1}$ at $N_3$ (225 kg $ha^{-l}$) and $N_4$ (300 kg $ha^{-1}$) were statistically on par during both the years at all the growth stages except at 30 DAS.

Interaction of irrigation scheduling and plant density was significant during both the cropping seasons at all the growth stages except at 30 DAS. Increase in irrigation level at same level of plant density significantly increased the stem dry matter $plant^{-1}$, while increase in plant density at same level of irrigation scheduling significantly reduced the stem dry matter $plant^{-1}$. At 60 DAS, $I_3$ x $P_1$, while at 90, 120 DAS and at physiological maturity $I_2$ x $P_1$ recorded on par with $I_3$ x $P_1$ and higher stem dry matter $plant^{-1}$ over others.

Irrigation scheduling and nitrogen level interaction effect differed significantly. Increase in irrigation from $I_1$ to $I_2$ coupled with increase in nitrogen level from $N_1$ to $N_3$ significantly increased the stem dry matter $plant^{-1}$. However, higher stem dry matter $plant^{-1}$ was recorded at $I_3$ x $N_4$ interaction and was on par with $I_2$ x $N_4$, $I_3$ X $N_3$ and $I_2$ x $N_4$ interactions and were significantly higher over others.

The interaction effect of Plant density and nitrogen level was significant. Increase in plant density at same level of nitrogen significantly reduced the stem dry matter $plant^{-1}$ but, increase in nitrogen level at same level of plant density differed significantly. With increase in nitrogen upto $N_3$ at $P_2$ and $P_3$ plant densities, and upto $N_2$ at $P_1$ plant density significantly increased the stem dry matter $plant^{-1}$. However, significantly higher stem dry matter $plant^{-1}$ was registered at $P_1$ x $N_2$ and was on par with $P_1$ x $N_3$ and $P_1$ x $N_4$ over other interactions.

The interaction of irrigation scheduling with plant density and nitrogen level (IxPxN) differed significantly. The higher level of irrigation coupled with higher level of nitrogen at lower level of plant density ($I_3XP_1XN_4$) recorded significantly higher stem dry matter $plant^{-1}$ as compared to other interaction effects.

4.2.3.3 Cob dry matter (g $plant^{-1}$) (cf. Table 23 and Appendix 18)

Cob dry matter $plant^{-1}$ differed significantly at 90, 120 DAS and at physiological maturity during both the years due to irrigation scheduling, plant density and nitrogen levels. The cob dry matter accumulation started after 60 DAS and increased rapidly between 90 and 120 DAS, after 120 DAS increased with a declining rate and attained maximum towards physiological maturity.

Increase in irrigation level from $I_1$ (0.6 IW/*CPE* ratio) to $I_2$ (0.9 IW/CPE ratio) significantly increased the cob dry matter $plant^{-1}$, between $I_2$ and $I_3$ (1.2 IW/CPE ratio) the cob dry matter $plant^{-l}$ was on par. The maximum cob dry matter $plant^{-1}$ recorded at $I_2$.

Increase in plant density from $P_1$ (55555 plants $ha^{-1}$) to $P_3$ (111111 plants $ha^{-l}$) significantly decreased the cob dry matter $plant^{-1}$. The higher and lower cob dry matter $plant^{-l}$ were recorded in $P_1$ and $P_3$ respectively.

The cob dry matter $plant^{-l}$ increased significantly with increase in nitrogen from $N_l$ (75 kg $ha^{-l}$) to $N_3$ (225 kg $ha^{-l}$), but $N_3$ and $N_4$ (300 kg $ha^{-l}$) were statistically on par.

**Table 21. Leaf dry matter (g plant$^{-1}$) at different growth stages of maize as influenced by irrigation scheduling, plant density and nitrogen levels (pooled data of two years)**

| Growth stages | 30 DAS | | | | 60 DAS | | | | 90 DAS | | | | 120 DAS | | | | Physiological maturity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 6.48 | 6.15 | 5.50 | **6.04** | 41.26 | 33.96 | 28.59 | **34.60** | 38.11 | 30.82 | 25.65 | **31.53** | 36.99 | 29.91 | 24.89 | **30.60** | 36.79 | 29.74 | 24.76 | 30.43 |
| $I_1N_2$ | 6.47 | 6.14 | 5.48 | **6.03** | 41.41 | 34.70 | 29.58 | **35.23** | 37.75 | 31.60 | 26.94 | **32.10** | 36.63 | 31.16 | 26.15 | **31.31** | 36.42 | 30.99 | 26.09 | 31.17 |
| $I_1N_3$ | 6.47 | 6.14 | 5.48 | **6.03** | 41.09 | 34.01 | 28.84 | **34.65** | 37.48 | 30.83 | 26.17 | **31.49** | 36.31 | 29.91 | 25.43 | **30.55** | 36.12 | 29.75 | 25.29 | 30.38 |
| $I_1N_4$ | 6.47 | 6.14 | 5.48 | **6.03** | 40.96 | 33.70 | 28.44 | **34.36** | 37.27 | 30.54 | 25.86 | **31.22** | 36.15 | 29.64 | 25.09 | **30.29** | 36.01 | 29.47 | 24.96 | 30.15 |
| **Mean** | **6.47** | **6.14** | **5.49** | **6.03** | **41.18** | **34.09** | **28.86** | **34.71** | **37.65** | **30.94** | **26.16** | **31.58** | **36.52** | **30.15** | **25.39** | **30.69** | **36.33** | **29.99** | **25.27** | **30.53** |
| $I_2N_1$ | 6.48 | 6.19 | 5.53 | **6.07** | 42.84 | 37.17 | 32.52 | **37.51** | 40.71 | 34.87 | 29.97 | **35.18** | 39.51 | 33.84 | 29.09 | **34.15** | 39.29 | 33.17 | 28.93 | 33.79 |
| $I_2N_2$ | 6.48 | 6.18 | 5.52 | **6.06** | 45.30 | 39.91 | 35.00 | **40.07** | 42.74 | 37.71 | 33.04 | **37.83** | 42.97 | 36.93 | 32.87 | **37.59** | 41.67 | 36.10 | 31.81 | 36.53 |
| $I_2N_3$ | 6.48 | 6.18 | 5.52 | **6.06** | 45.16 | 42.88 | 37.04 | **41.69** | 42.68 | 41.08 | 35.68 | **39.81** | 43.51 | 40.63 | 36.24 | **40.13** | 41.68 | 38.18 | 33.92 | 37.93 |
| $I_2N_4$ | 6.48 | 6.18 | 5.52 | **6.06** | 45.25 | 42.92 | 37.12 | **41.76** | 42.83 | 41.24 | 44.20 | **42.75** | 43.58 | 40.78 | 36.52 | **40.29** | 41.70 | 38.22 | 34.22 | 38.05 |
| **Mean** | **6.48** | **6.18** | **5.53** | **6.06** | **44.64** | **40.72** | **35.42** | **40.26** | **42.24** | **38.72** | **35.72** | **38.89** | **42.39** | **38.04** | **33.68** | **38.04** | **41.09** | **36.41** | **32.22** | **36.57** |
| $I_3N_1$ | 6.48 | 6.18 | 5.53 | **6.06** | 42.79 | 38.38 | 33.91 | **38.36** | 40.73 | 35.68 | 31.29 | **35.90** | 39.62 | 35.12 | 30.75 | **35.16** | 38.90 | 34.42 | 30.67 | 34.66 |
| $I_3N_2$ | 6.48 | 6.18 | 5.52 | **6.06** | 45.51 | 41.91 | 37.67 | **41.70** | 42.69 | 39.96 | 35.04 | **39.23** | 42.44 | 39.36 | 34.95 | **38.91** | 41.23 | 38.01 | 33.81 | 37.68 |
| $I_3N_3$ | 6.48 | 6.18 | 5.52 | **6.06** | 46.88 | 45.44 | 39.82 | **44.04** | 42.91 | 42.14 | 37.28 | **40.78** | 42.79 | 42.85 | 37.90 | **41.18** | 41.52 | 40.92 | 36.52 | 39.65 |
| $I_3N_4$ | 6.48 | 6.17 | 5.52 | **6.06** | 46.94 | 45.56 | 39.96 | **44.15** | 42.95 | 42.38 | 37.44 | **40.92** | 42.98 | 42.97 | 37.94 | **41.30** | 41.69 | 40.93 | 36.54 | 39.72 |
| **Mean** | **6.48** | **6.18** | **5.52** | **6.06** | **45.53** | **42.82** | **37.84** | **42.06** | **42.32** | **40.04** | **35.26** | **39.21** | **41.96** | **40.07** | **35.38** | **39.14** | **40.83** | **38.57** | **34.38** | **37.93** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 6.48 | 6.18 | 5.52 | **6.06** | 42.30 | 36.50 | 31.67 | **36.82** | 39.85 | 33.79 | 28.97 | **34.20** | 38.71 | 32.96 | 28.24 | **33.30** | 38.32 | 32.44 | 28.12 | **32.96** |
| **N2** | 6.47 | 6.16 | 5.51 | **6.05** | 44.07 | 38.84 | 34.08 | **39.00** | 41.06 | 36.42 | 31.68 | **36.39** | 40.68 | 35.81 | 31.32 | **35.94** | 39.77 | 35.03 | 30.57 | **35.12** |
| **N3** | 6.48 | 6.16 | 5.51 | **6.05** | 44.38 | 40.78 | 35.23 | **40.13** | 41.02 | 38.01 | 33.04 | **37.36** | 40.87 | 37.80 | 33.19 | **37.28** | 39.77 | 36.28 | 31.91 | **35.99** |
| **N4** | 6.48 | 6.16 | 5.51 | **6.05** | 44.38 | 40.72 | 35.17 | **40.09** | 41.01 | 38.05 | 35.83 | **38.30** | 40.90 | 37.79 | 33.18 | **37.29** | 39.80 | 36.20 | 31.90 | **35.97** |
| **Mean** | **6.48** | **6.17** | **5.51** | **6.05** | **43.78** | **39.21** | **34.04** | **39.01** | **40.74** | **36.57** | **32.38** | **36.56** | **40.29** | **36.09** | **31.48** | **35.95** | **39.42** | **34.99** | **30.62** | **35.01** |

| | 30 DAS | | 60 DAS | | 90 DAS | | 120 DAS | | Physiological maturity | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | 0.005 | 0.016 | 0.022 | 0.071 | 0.027 | 0.089 | 0.030 | 0.097 | 0.025 | 0.081 |
| **Plant Density (P)** | 0.007 | 0.020 | 0.062 | 0.047 | 0.020 | 0.058 | 0.017 | 0.050 | 0.017 | 0.049 |
| **Nitrogen levels (N)** | 0.003 | 0.009 | 0.010 | 0.029 | 0.014 | 0.041 | 0.006 | 0.017 | 0.004 | 0.011 |
| **I X P** | 0.012 | 0.035 | 0.028 | 0.081 | 0.034 | 0.100 | 0.030 | 0.087 | 0.029 | 0.084 |
| **I X N** | 0.006 | 0.015 | 0.017 | 0.048 | 0.025 | 0.068 | 0.011 | 0.030 | 0.007 | 0.020 |
| **P X N** | 0.006 | 0.015 | 0.017 | 0.048 | 0.025 | 0.068 | 0.011 | 0.030 | 0.007 | 0.020 |
| **I X P X N** | 0.009 | 0.026 | 0.030 | 0.084 | 0.043 | 0.118 | 0.186 | 0.052 | 0.012 | 0.034 |

DAS: Days after sowing

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density (P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$ Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$;$N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$;$N_4$ = 300 Kg ha$^{-1}$

Table 22. Stem dry matter (g plant$^{-1}$) at different growth stages of maize as influenced by irrigation scheduling, plant density and nitrogen levels (pooled data of two years)

| Growth stages | 30 DAS | | | | 60 DAS | | | | 90 DAS | | | | 120 DAS | | | | Physiological maturity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 0.22 | 0.22 | 0.22 | **0.22** | 29.99 | 24.43 | 20.37 | **24.93** | 52.42 | 43.14 | 35.90 | **43.82** | 51.91 | 43.14 | 35.91 | **43.65** | 50.39 | 43.20 | 35.90 | **43.16** |
| $I_1N_2$ | 0.22 | 0.22 | 0.22 | **0.22** | 31.04 | 26.27 | 22.09 | **26.47** | 52.43 | 45.83 | 39.68 | **45.98** | 52.16 | 45.88 | 39.80 | **45.95** | 52.15 | 45.83 | 39.69 | **45.89** |
| $I_1N_3$ | 0.22 | 0.22 | 0.22 | **0.22** | 31.01 | 25.97 | 21.83 | **26.27** | 51.25 | 44.29 | 38.11 | **44.55** | 51.74 | 44.29 | 38.26 | **44.76** | 51.23 | 44.00 | 37.78 | **44.34** |
| $I_1N_4$ | 0.22 | 0.22 | 0.22 | **0.22** | 30.77 | 25.76 | 21.60 | **26.04** | 51.00 | 43.81 | 37.74 | **44.18** | 51.38 | 43.92 | 37.78 | **44.36** | 51.00 | 43.69 | 37.49 | **44.06** |
| **Mean** | **0.22** | **0.22** | **0.22** | **0.22** | **30.70** | **25.61** | **21.47** | **25.93** | **51.78** | **44.27** | **37.86** | **44.63** | **51.80** | **44.31** | **37.94** | **44.68** | **51.19** | **44.18** | **37.71** | **44.36** |
| $I_2N_1$ | 0.22 | 0.22 | 0.22 | **0.22** | 30.62 | 27.05 | 23.07 | **26.91** | 53.95 | 46.29 | 39.34 | **46.53** | 51.27 | 46.29 | 39.35 | **45.63** | 46.06 | 45.89 | 39.35 | **43.77** |
| $I_2N_2$ | 0.22 | 0.22 | 0.22 | **0.22** | 32.87 | 30.32 | 25.80 | **29.66** | 58.07 | 54.71 | 47.76 | **53.51** | 58.07 | 55.20 | 48.25 | **53.84** | 57.99 | 54.21 | 48.13 | **53.44** |
| $I_2N_3$ | 0.22 | 0.22 | 0.22 | **0.22** | 33.18 | 32.57 | 27.94 | **31.23** | 58.15 | 57.84 | 50.69 | **55.56** | 58.85 | 59.96 | 53.12 | **57.31** | 58.10 | 59.50 | 52.38 | **56.66** |
| $I_2N_4$ | 0.22 | 0.22 | 0.22 | **0.22** | 33.29 | 32.64 | 27.93 | **31.29** | 58.29 | 53.11 | 50.60 | **54.00** | 59.00 | 60.20 | 53.30 | **57.50** | 58.08 | 59.53 | 52.50 | **56.70** |
| **Mean** | **0.22** | **0.22** | **0.22** | **0.22** | **32.49** | **30.64** | **26.18** | **29.77** | **57.11** | **52.99** | **47.10** | **52.40** | **56.80** | **55.41** | **48.51** | **53.57** | **55.06** | **54.78** | **48.09** | **52.64** |
| $I_3N_1$ | 0.22 | 0.22 | 0.22 | **0.22** | 30.40 | 26.56 | 22.61 | **26.52** | 53.39 | 45.23 | 38.06 | **45.56** | 50.16 | 45.24 | 38.21 | **44.53** | 44.77 | 44.91 | 38.06 | **42.58** |
| $I_3N_2$ | 0.22 | 0.22 | 0.22 | **0.22** | 33.12 | 30.55 | 26.43 | **30.03** | 58.12 | 54.90 | 47.52 | **53.51** | 58.12 | 55.43 | 48.26 | **53.94** | 57.28 | 55.20 | 48.13 | **53.53** |
| $I_3N_3$ | 0.22 | 0.22 | 0.22 | **0.22** | 33.29 | 32.80 | 28.50 | **31.53** | 58.48 | 58.15 | 50.44 | **55.69** | 59.04 | 60.31 | 53.78 | **57.71** | 58.27 | 59.50 | 53.43 | **57.07** |
| $I_3N_4$ | 0.22 | 0.22 | 0.22 | **0.22** | 33.43 | 32.92 | 28.69 | **31.68** | 58.54 | 58.33 | 50.53 | **55.80** | 59.06 | 60.43 | 53.86 | **57.78** | 58.29 | 59.65 | 53.49 | **57.14** |
| **Mean** | **0.22** | **0.22** | **0.22** | **0.22** | **32.56** | **30.71** | **26.56** | **29.94** | **57.13** | **54.15** | **46.63** | **52.64** | **56.59** | **55.35** | **48.53** | **53.49** | **54.65** | **54.81** | **48.28** | **52.58** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 0.22 | 0.22 | 0.22 | **0.22** | 30.34 | 26.01 | 22.02 | **26.12** | 53.25 | 44.89 | 37.77 | **45.30** | 51.11 | 44.89 | 37.82 | **44.61** | 47.07 | 44.66 | 37.77 | 43.17 |
| **N2** | 0.22 | 0.22 | 0.22 | **0.22** | 32.34 | 29.04 | 24.77 | **28.72** | 56.21 | 51.81 | 44.99 | **51.00** | 56.12 | 52.17 | 45.44 | **51.24** | 55.80 | 51.75 | 45.31 | **50.95** |
| **N3** | 0.22 | 0.22 | 0.22 | **0.22** | 32.50 | 30.45 | 26.09 | **29.68** | 55.96 | 53.43 | 46.41 | **51.93** | 56.54 | 54.85 | 48.39 | **53.26** | 55.86 | 54.34 | 47.86 | **52.69** |
| **N4** | 0.22 | 0.22 | 0.22 | **0.22** | 32.50 | 30.44 | 26.07 | **29.67** | 55.94 | 51.75 | 46.29 | **51.33** | 56.48 | 54.85 | 48.31 | **53.21** | 55.79 | 54.29 | 47.83 | **52.63** |
| **Mean** | **0.22** | **0.22** | **0.22** | **0.22** | **31.92** | **28.99** | **24.74** | **28.55** | **55.34** | **50.47** | **43.86** | **49.89** | **55.06** | **51.69** | **44.99** | **50.58** | **53.63** | **51.26** | **44.69** | **49.86** |

| | 30 DAS | | 60 DAS | | 90 DAS | | 120 DAS | | Physiological maturity | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | NS | NS | 0.013 | 0.042 | 0.026 | 0.085 | 0.036 | 0.118 | 0.220 | 0.719 |
| **Plant Density (P)** | NS | NS | 0.010 | 0.029 | 0.025 | 0.072 | 0.018 | 0.051 | 0.244 | 0.712 |
| **Nitrogen levels (N)** | NS | NS | 0.010 | 0.027 | 0.028 | 0.078 | 0.013 | 0.037 | 0.273 | 0.756 |
| **I X P** | NS | NS | 0.017 | 0.051 | 0.042 | 0.124 | 0.030 | 0.089 | 0.423 | 1.233 |
| **I X N** | NS | NS | 0.171 | 0.474 | 0.049 | 0.136 | 0.023 | 0.064 | 0.473 | 1.310 |
| **P X N** | NS | NS | 0.171 | 0.474 | 0.049 | 0.136 | 0.023 | 0.064 | 0.473 | 1.310 |
| **I X P X N** | NS | NS | 0.030 | 0.082 | 0.085 | 0.235 | 0.040 | 0.111 | 0.819 | 2.269 |

DAS: Days after sowing

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$

**Table 23. Cob dry matter (g plant$^{-1}$) at different growth stages of maize as influenced by irrigation scheduling, plant density and nitrogen levels (pooled data of two years)**

| Growth stages | 90 DAS | | | | 120 DAS | | | | Physiological maturity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 64.07 | 49.11 | 38.65 | **50.61** | 147.68 | 102.35 | 77.22 | **109.08** | 158.50 | 109.45 | 82.52 | **116.82** |
| $I_1N_2$ | 63.33 | 52.71 | 43.75 | **53.26** | 146.76 | 112.47 | 92.92 | **117.39** | 159.17 | 121.95 | 99.53 | **126.88** |
| $I_1N_3$ | 61.71 | 49.15 | 39.75 | **50.20** | 140.59 | 102.13 | 81.57 | **108.10** | 151.87 | 108.70 | 98.08 | **119.55** |
| $I_1N_4$ | 61.44 | 48.57 | 39.06 | **49.69** | 139.59 | 101.38 | 80.25 | **107.07** | 151.07 | 108.09 | 87.11 | **115.42** |
| **Mean** | **62.64** | **49.88** | **40.30** | **50.94** | **143.66** | **104.58** | **82.99** | **110.41** | **155.15** | **112.05** | **91.81** | **119.67** |
| $I_2N_1$ | 64.85 | 49.23 | 38.94 | **51.00** | 153.03 | 101.73 | 75.22 | **109.99** | 169.77 | 111.47 | 81.97 | **121.07** |
| $I_2N_2$ | 69.09 | 59.31 | 47.08 | **58.50** | 165.85 | 126.65 | 100.59 | **131.03** | 180.93 | 140.09 | 110.84 | **143.95** |
| $I_2N_3$ | 69.28 | 62.84 | 50.00 | **60.71** | 166.81 | 135.00 | 107.58 | **136.46** | 181.49 | 145.95 | 117.26 | **148.23** |
| $I_2N_4$ | 69.37 | 63.01 | 50.19 | **60.85** | 167.00 | 135.74 | 109.42 | **137.38** | 181.82 | 146.13 | 128.36 | **152.10** |
| **Mean** | **68.14** | **58.60** | **46.55** | **57.76** | **163.17** | **124.78** | **98.20** | **128.72** | **178.50** | **135.91** | **109.61** | **141.34** |
| $I_3N_1$ | 64.13 | 47.88 | 37.58 | **49.86** | 152.64 | 99.00 | 72.42 | **108.02** | 168.73 | 108.44 | 78.91 | **118.70** |
| $I_3N_2$ | 63.87 | 58.34 | 46.95 | **56.39** | 166.01 | 127.32 | 100.24 | **131.19** | 181.12 | 140.40 | 110.52 | **144.01** |
| $I_3N_3$ | 69.33 | 63.19 | 50.38 | **60.96** | 167.21 | 136.24 | 108.68 | **137.38** | 181.50 | 146.53 | 117.07 | **148.37** |
| $I_3N_4$ | 69.91 | 63.41 | 55.41 | **62.91** | 167.66 | 137.88 | 109.28 | **138.27** | 181.78 | 147.46 | 117.82 | **149.02** |
| **Mean** | **66.81** | **58.20** | **47.58** | **57.53** | **163.38** | **125.11** | **97.66** | **128.72** | **178.28** | **135.71** | **106.08** | **140.02** |
| **NXP Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 64.35 | 48.74 | 38.39 | **50.49** | 151.11 | 101.03 | 74.95 | **109.03** | 165.66 | 109.79 | 81.13 | **118.86** |
| **N2** | 65.43 | 56.79 | 45.93 | **56.05** | 159.54 | 122.15 | 97.92 | **126.54** | 173.74 | 134.14 | 106.96 | **138.28** |
| **N3** | 66.77 | 58.39 | 46.71 | **57.29** | 158.21 | 124.46 | 99.27 | **127.31** | 171.62 | 133.72 | 110.80 | **138.71** |
| **N4** | 66.90 | 58.33 | 48.22 | **57.82** | 158.08 | 125.00 | 99.65 | **127.58** | 171.56 | 133.89 | 111.09 | **138.85** |
| **Mean** | **65.86** | **55.56** | **44.81** | **55.41** | **156.74** | **118.16** | **92.95** | **122.61** | **170.64** | **127.89** | **102.50** | **133.68** |

| | 90 DAS | | 120 DAS | | Physiological maturity | |
|---|---|---|---|---|---|---|
| **Comparing Means** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | 0.290 | 0.945 | 0.085 | 0.276 | 0.510 | 1.663 |
| **Plant Population (P)** | 0.241 | 0.786 | 0.157 | 0.458 | 0.459 | 1.340 |
| **Nitrogen levels (N)** | 0.285 | 0.790 | 0.099 | 0.275 | 0.560 | 1.551 |
| **I X P** | 0.418 | 1.219 | 0.272 | 0.794 | 0.795 | 2.321 |
| **I X N** | 0.494 | 1.369 | 0.172 | 0.476 | 0.969 | 2.686 |
| **P X N** | 0.494 | 1.369 | 0.172 | 0.476 | 0.969 | 2.686 |
| **I X P X N** | 0.855 | 2.371 | 0.298 | 0.825 | 1.679 | 4.653 |

DAS: Days after sowing

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$  Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$;$N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$;$N_4$ = 300 Kg ha$^{-1}$

The interaction of irrigation scheduling and plant density on cob dry matter plant$^{-l}$ registered significant difference at all the growth stages during both the years. Increase in irrigation scheduling from $I_1$ to $I_2$ at the same level of plant density significantly increased the cob dry matter plant$^{-1}$. But, at $I_2$ and $I_3$ irrigation level at same plant density, the cob dry matter plant$^{-l}$ was on par. Increase in plant density at same level of irrigation significantly decreased the cob dry matter plant$^{-1}$. Significantly higher cob dry matter plant$^{-l}$ was recorded in $I_2$ x $P_1$ interaction over others, however $I_2$ x $P_1$ and $I_3$ x $P_1$ were on par.

The interaction effect of irrigation scheduling and nitrogen was significant. Increase in irrigation level from $I_1$ to $I_2$ coupled with increase in nitrogen level from $N_1$ to $N_3$ significantly increased cob dry matter plant$^{-1}$. Significantly higher cob dry matter plant$^{-l}$ was recorded at $I_2$x$N_4$ over other interactions at physiological maturity.

The cob dry matter plant$^{-1}$ differed significantly due to interaction effect of plant density and nitrogen level. Increase in plant density at same level of nitrogen significantly decreased the cob dry matter plant$^{-1}$. Increase in nitrogen level from $N_1$ to $N_2$ at $P_1$ plant density and from $N_1$ to $N_3$ at $P_2$ and $P_3$ plant densities significantly increased the cob dry matter plant$^{-1}$. However at $P_{1,}$ further increase in nitrogen from $N_2$ to $N_4$, at $P_2$ and $P_3$ from $N_3$ to $N_4$ , cob dry matter plant$^{-1}$ recorded was on par.

The interaction effect due to irrigation scheduling, plant density and nitrogen level caused significant difference in cob dry matter plant$^{-1}$. Irrigation at $I_2$ with plant density at $P_1$ coupled with nitrogen level at $N_3$ recorded higher cob dry matter plant$^{-1}$ and was on par with $I_2XP_lXN_4$, $I_3XP_1XN_3$ and $I_3XP_lXN_4$. However these combinations recorded significantly higher cob dry matter plant$^{-1}$ than other interactions.

4.2.3.5 Total dry matter plant$^{-l}$ (cf. Table 24; Appendix 19 and Appendix 20)

Total dry matter plant$^{-1}$ varied significantly due to irrigation scheduling, plant density and nitrogen level at all the growth stages during both the years. The total dry matter increased rapidly from 30 DAS upto 60 DAS, then the increase was constant upto 120 DAS and was marginal towards physiological maturity.

Increase in irrigation level from $I_1$ to $I_3$ increased the total dry matter plant$^{-1}$ significantly at 60, 90, 120 DAS and at physiological maturity except at 30 DAS. At 30 DAS, total dry matter plant$^{-1}$ did not differ significantly due to irrigation scheduling. When averaged over the years, higher total dry matter plant$^{-1}$ was recorded at $I_3$ [1.2 IW /CPE ratio] over other irrigation levels.

At all the growth stages total dry matter plant$^{-1}$ significantly decreased with increase in plant density from $P_1$ (55555 plants ha$^{-1}$) to $P_3$(111111 plants ha$^{-1}$). Significantly higher total dry matter plant$^{-1}$ was recorded at $P_1$ plant density.

Except at 30 DAS, in other growth stages total dry matter plant$^{-1}$ increased with increase in nitrogen level from $N_1$ to $N_3$. However, the total dry matter plant$^{-1}$ at $N_3$ and $N_4$ was on par.

The interaction effect of irrigation scheduling and plant density on total dry matter plant$^{-1}$ was significant at all the growth stages except at 30 DAS. At 60, 90, 120 DAS and at physiological maturity increase in irrigation level from $I_1$ to $I_3$ at same level of plant density significantly increased the total dry matter plant$^{-1}$. Increase in plant density from $P_1$ to $P_3$ at same level of irrigation scheduling significantly reduced the total dry matter plant$^{-1}$. Significantly higher total dry matter plant$^{-1}$ was registered by irrigation at $I_3$ (1.2 IW /CPE ratio) coupled with $P_1$ (55555 plants ha$^{-1}$) compared to other interactions, while it was significantly lower for irrigation at $I_1$ (0.6 IW /CPE ratio) coupled with plant density at $P_3$ (111111 plants ha$^{-1}$).

Interaction effect for irrigation scheduling and nitrogen level (IxN) was significant. The increase in irrigation level from $I_1$ to $I_3$ coupled with increase in nitrogen level from $N_1$ to $N_4$ significantly increased the total dry matter plant$^{-1}$. Significantly higher and lower total dry matter plant$^{-1}$ was recorded at $I_3$ x $N_4$ and $I_1$ X $N_1$ respectively.

The interaction effect of plant density and nitrogen level (PxN) caused significant difference in total dry matter plant$^{-1}$ at all the growth stages except at 30 DAS. Increase in plant density from $P_1$ to $P_3$ at same level of nitrogen significantly reduced the total dry matter plant$^{-1}$. However, increase in nitrogen level from $N_1$ to $N_2$ at $P_1$ plant density, and from $N_1$ to $N_3$ at $P_2$ and $P_3$ plant densities significantly increased the total dry matter plant$^{-1}$.

Interaction effect of irrigation scheduling, plant density and nitrogen level (IxPxN) had significant influence on total dry matter plant$^{-1}$ at all the growth stages except at 30 DAS during both the years. Increase in irrigation level from $I_1$ to $I_3$ coupled with increase in nitrogen from $N_1$ to $N_2$ at $P_1$ plant density and from $N_1$ from $N_1$ to $N_3$ at $P_2$ and $P_3$ plant densities significantly increased the total dry matter plant$^{-1}$. At all the growth stages except at 30 DAS during both the years significantly higher total dry matter plant$^{-1}$ was recorded for irrigation scheduling at $I_3$ coupled with plant density at $P_1$ and nitrogen level of $N_3$ or $N_4$ over other interaction effects.

## 4.2.4 Yield and yield parameters

### 4.2.4.1 Grain yield (kg ha$^{-l}$) (cf. Table 25)

Grain yield (kg ha$^{-1}$) of maize differed significantly due to irrigation scheduling, plant density and nitrogen levels. The trend was similar during 1998-99 and 1999-2000.

When averaged over the seasons, increase in irrigation level from $I_1$(0.6 IW/CPE ratio) to $I_2$ (0.9 IW/CPE ratio) significantly increased the grain yield (6210 to 7692 kg ha$^{-l}$ respectively). The irrigation level at $I_2$ and $I_3$ registered statistically on par grain yield (7962 and 7664 kg ha$^{-l}$ respectively).

The increase in plant density from $P_1$ (normal) to $P_3$ (very high) through $P_2$ (high) increased the grain yield significantly. Plant density at $P_3$ (111111 plants ha$^{-l}$) recorded significantly higher grain yield (7373 kg ha$^{-l}$) as compared to $P_2$ (7253 kg ha$^{-l}$) and $P_1$ (6941 kg ha$^{-l}$).

Increase in nitrogen level from $N_l$ (75 kg ha$^{-l}$) to $N_3$ (225 kg ha$^{-l}$) significantly increased the grain yield (6101 to 7591 kg ha$^{-l}$ respectively). However, the grain yield at $N_3$ and $N_4$ (300 kg ha$^{-l}$) were on par ( 7591 and 7586 kg ha$^{-1}$ respectively).

The interaction effects of irrigation scheduling and plant density were significant. The increase in irrigation level from $I_1$ to $I_2$ coupled with increase in plant density from $P_1$ to $P_3$ significantly increased the grain yield. Significantly higher grain yield (7933 kg ha$^{-l}$) was obtained at $I_2$ coupled with plant density of $P_3$. This was on par with $I_3$ x $P_3$ (7888 kg ha$^{-l}$) and these were significantly higher over other interactions.

Grain yield differed significantly due to interaction effect of irrigation scheduling and nitrogen level. Increase in nitrogen level from $N_1$ to $N_2$ at $I_1$ and from $N_l$ to $N_3$ at $I_2$ and $I_3$ significantly increased the grain yield. Irrigation scheduling at $I_3$ (1.2 IW/CPE ratio) coupled with nitrogen level at $N_4$ (300 kg ha$^{-l}$) recorded significantly higher grain yield (8361 kg ha$^{-l}$) over other interactions, however $I_2$ x $N_3$ (8310 kg ha$^{-1}$) and $I_3$ X $N_3$ (8316 kg ha$^{-l}$) were on par with $I_3$ x $N_4$

The grain yield differed significantly due to interaction effect of plant density and nitrogen level. Increase in nitrogen from $N_1$ to $N_2$ at $P_1$ plant density, $N_l$ to $N_3$ at $P_2$ and $P_3$ plant densities significantly increased the grain yield. Significantly higher grain yield of 8037 kg ha$^{-l}$ was recorded at $P_3$ x $N_3$ treatment combination over others except $P_3$ x $N_4$ (8017 kg ha$^{-1}$) and were on par.

Grain yield differed significantly due to interaction effect of irrigation scheduling, plant density and nitrogen levels (IxPxN). Increase in irrigation scheduling from $I_1$ to $I_2$ coupled with increase of plant density from $P_1$ to $P_3$ and nitrogen level from $N_l$ to $N_3$ significantly increased the grain yield. The grain yield recorded at $I_2$ x $P_3$ X $N_3$ (8886 kg ha$^{-l}$), $I_2$ x $P_3$ X $N_4$ (8894 kg ha$^{-l}$), $I_3$ x $P_3$ X $N_3$ (8892 kg ha$^{-l}$) and $I_3$ x $P_3$ X $N_4$ (8922 kg ha$^{-l}$) was on par and these treatments were significantly higher over others.

### 4.2.4.2 Stover yield (kg ha$^{-l}$) (cf. Table 26)

Maize stover yield (kg ha$^{-l}$) differed significantly due to irrigation scheduling, plant density and nitrogen levels and maintained the same trend during both the years.

Over the seasons, the effect of irrigation scheduling was significant. Increase in irrigation level from $I_1$ to $I_3$ significantly increased the stover yield and recorded significantly higher stover yield (10221 kg ha$^{-1}$) at $I_3$ (1.2 IW/CPE ratio).

**Table 24. Total Dry matter (g plant $^{-1}$) at different growth stages of maize as influenced by irrigation scheduling, plant density and nitrogen levels (pooled data of two years)**

| Growth stages | 30 DAS | | | | 60 DAS | | | | 90 DAS | | | | 120 DAS | | | | Physiological maturity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 6.70 | 6.37 | 5.72 | 6.26 | 71.25 | 58.39 | 48.96 | 59.53 | 154.60 | 123.07 | 100.20 | 125.96 | 236.58 | 175.40 | 138.02 | 183.33 | 245.68 | 182.39 | 143.18 | 190.42 |
| $I_1N_2$ | 6.69 | 6.36 | 5.70 | 6.26 | 72.45 | 60.97 | 51.67 | 61.70 | 153.51 | 130.14 | 110.37 | 131.34 | 235.55 | 189.51 | 158.87 | 194.64 | 247.74 | 198.77 | 165.31 | 203.94 |
| $I_1N_3$ | 6.69 | 6.36 | 5.70 | 6.26 | 72.10 | 59.98 | 50.67 | 60.92 | 150.44 | 124.27 | 104.03 | 126.25 | 228.64 | 176.33 | 145.26 | 183.41 | 239.22 | 182.45 | 161.15 | 194.27 |
| $I_1N_4$ | 6.69 | 6.36 | 5.70 | 6.26 | 71.73 | 59.46 | 50.04 | 60.41 | 149.71 | 122.92 | 102.66 | 125.10 | 227.12 | 174.94 | 143.12 | 181.73 | 238.08 | 181.25 | 149.56 | 189.63 |
| Mean | 6.69 | 6.36 | 5.71 | 6.26 | 71.88 | 59.70 | 50.34 | 60.64 | 152.07 | 125.10 | 104.32 | 127.16 | 231.97 | 179.05 | 146.32 | 185.78 | 242.68 | 186.22 | 154.80 | 194.57 |
| $I_2N_1$ | 6.70 | 6.41 | 5.75 | 6.26 | 73.46 | 64.22 | 55.59 | 64.42 | 159.51 | 130.39 | 108.25 | 132.72 | 243.81 | 181.86 | 143.66 | 189.78 | 255.12 | 190.53 | 150.25 | 198.63 |
| $I_2N_2$ | 6.70 | 6.40 | 5.74 | 6.26 | 78.17 | 70.23 | 60.80 | 69.73 | 169.90 | 151.73 | 127.88 | 149.84 | 266.89 | 218.78 | 181.71 | 222.46 | 280.59 | 230.40 | 190.78 | 233.92 |
| $I_2N_3$ | 6.70 | 6.40 | 5.74 | 6.26 | 78.34 | 75.45 | 64.98 | 72.92 | 170.11 | 161.76 | 136.37 | 156.08 | 269.17 | 235.59 | 196.94 | 233.90 | 281.27 | 243.63 | 203.56 | 242.82 |
| $I_2N_4$ | 6.70 | 6.40 | 5.74 | 6.26 | 78.54 | 75.56 | 65.05 | 73.05 | 170.49 | 157.36 | 144.99 | 157.61 | 269.58 | 236.72 | 199.24 | 235.18 | 281.60 | 243.88 | 215.08 | 246.85 |
| Mean | 6.70 | 6.40 | 5.74 | 6.26 | 77.13 | 71.37 | 61.61 | 70.03 | 167.50 | 150.31 | 129.37 | 149.06 | 262.36 | 218.24 | 180.39 | 220.33 | 274.65 | 227.11 | 189.92 | 230.56 |
| $I_3N_1$ | 6.70 | 6.40 | 5.75 | 6.26 | 73.19 | 64.94 | 56.52 | 64.88 | 158.25 | 128.79 | 106.93 | 131.32 | 242.42 | 179.36 | 141.38 | 187.72 | 252.40 | 187.77 | 147.64 | 195.94 |
| $I_3N_2$ | 6.70 | 6.40 | 5.74 | 6.26 | 78.63 | 72.46 | 64.10 | 71.73 | 164.68 | 153.20 | 129.51 | 149.13 | 266.57 | 222.11 | 183.45 | 224.04 | 279.63 | 233.61 | 192.46 | 235.23 |
| $I_3N_3$ | 6.70 | 6.40 | 5.74 | 6.26 | 80.17 | 78.24 | 68.32 | 75.58 | 170.72 | 163.48 | 138.10 | 157.43 | 269.04 | 239.40 | 200.36 | 236.27 | 281.29 | 246.95 | 207.02 | 245.09 |
| $I_3N_4$ | 6.70 | 6.39 | 5.74 | 6.26 | 80.37 | 78.48 | 68.65 | 75.83 | 171.40 | 164.12 | 143.38 | 159.63 | 269.70 | 241.28 | 201.08 | 237.35 | 281.76 | 248.04 | 207.85 | 245.88 |
| Mean | 6.70 | 6.40 | 5.74 | 6.26 | 78.09 | 73.53 | 64.40 | 72.01 | 166.26 | 152.40 | 129.48 | 149.38 | 261.93 | 220.54 | 181.57 | 221.35 | 273.77 | 229.09 | 188.74 | 230.54 |
| P X N Interaction | P1 | P2 | P3 | Mean | P1 | P2 | P3 | Mean | P1 | P2 | P3 | Mean | P1 | P2 | P3 | Mean | P1 | P2 | P3 | Mean |
| N1 | 6.70 | 6.39 | 5.74 | 6.26 | 72.63 | 62.52 | 53.69 | 62.95 | 157.45 | 127.42 | 105.13 | 130.00 | 240.94 | 178.87 | 141.02 | 186.94 | 251.07 | 186.90 | 147.02 | 195.00 |
| N2 | 6.70 | 6.39 | 5.73 | 6.26 | 76.42 | 67.89 | 58.86 | 67.72 | 162.70 | 145.02 | 122.59 | 143.44 | 256.34 | 210.13 | 174.68 | 213.72 | 269.32 | 220.93 | 182.85 | 224.37 |
| N3 | 6.70 | 6.39 | 5.73 | 6.26 | 76.87 | 71.22 | 61.32 | 69.81 | 163.76 | 149.84 | 126.17 | 146.59 | 255.62 | 217.11 | 180.85 | 217.86 | 267.26 | 224.34 | 190.58 | 227.39 |
| N4 | 6.70 | 6.38 | 5.73 | 6.26 | 76.88 | 71.17 | 61.25 | 69.76 | 163.87 | 148.13 | 130.34 | 147.45 | 255.47 | 217.65 | 181.15 | 218.09 | 267.15 | 224.39 | 190.83 | 227.46 |
| Mean | 6.70 | 6.39 | 5.73 | 6.26 | 75.70 | 68.20 | 58.78 | 67.56 | 161.94 | 142.60 | 121.06 | 141.87 | 252.09 | 205.94 | 169.42 | 209.15 | 263.70 | 214.14 | 177.82 | 218.55 |

| | 30 DAS | | 60 DAS | | 90 DAS | | 120 DAS | | Physiological maturity | |
|---|---|---|---|---|---|---|---|---|---|---|
| Comparing Means of | SEm ± | CD ( 0.05) | SEm ± | CD ( 0.05) | SEm ± | CD ( 0.05) | SEm ± | CD ( 0.05) | SEm ± | CD ( 0.05) |
| Irrigation (I) | 0.052 | 0.170 | 0.031 | 0.101 | 0.084 | 0.273 | 0.128 | 0.418 | 0.134 | 0.438 |
| Plant Density (P) | 0.050 | 0.146 | 0.024 | 0.071 | 0.075 | 0.219 | 0.151 | 0.440 | 0.163 | 0.476 |
| Nitrogen levels (N) | 0.055 | 0.154 | 0.011 | 0.032 | 0.028 | 0.077 | 0.042 | 0.156 | 0.045 | 0.125 |
| I X P | 0.087 | 0.253 | 0.042 | 0.123 | 0.130 | 0.380 | 0.261 | 0.762 | 0.282 | 0.823 |
| I X N | 0.096 | 0.266 | 0.020 | 0.055 | 0.048 | 0.133 | 0.072 | 0.200 | 0.078 | 0.216 |
| P X N | 0.096 | 0.266 | 0.020 | 0.055 | 0.048 | 0.133 | 0.072 | 0.200 | 0.078 | 0.216 |
| I X P X N | 0.166 | 0.461 | 0.034 | 0.095 | 0.083 | 0.230 | 0.125 | 0.347 | 0.135 | 0.374 |

DAS: Days after sowing

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$;$N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$;$N_4$ = 300 Kg ha$^{-1}$

**Table 25. Grain yield (kg ha$^{-1}$) of maize as influenced by irrigation scheduling, plant density and nitrogen levels**

| Year | 1998-99 | | | | 1999-2000 | | | | Pooled | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** |
| **$I_1N_1$** | 6005 | 5738 | 5544 | **5762** | 6396 | 6139 | 5962 | **6166** | 6201 | 5939 | 5753 | **5964** |
| **$I_1N_2$** | 6146 | 6625 | 6765 | **6512** | 6478 | 6806 | 6974 | **6753** | 6312 | 6716 | 6870 | **6632** |
| **$I_1N_3$** | 5949 | 6081 | 6170 | **6067** | 6079 | 6105 | 6497 | **6227** | 6014 | 6093 | 6334 | **6147** |
| **$I_1N_4$** | 5943 | 5998 | 6087 | **6009** | 6097 | 6063 | 6386 | **6182** | 6020 | 6031 | 6237 | **6096** |
| **Mean** | **6011** | **6111** | **6142** | **6088** | **6263** | **6278** | **6455** | **6332** | **6137** | **6194** | **6298** | **6210** |
| **$I_2N_1$** | 6554 | 6013 | 5510 | **6026** | 7162 | 6333 | 5848 | **6448** | 6858 | 6173 | 5679 | **6237** |
| **$I_2N_2$** | 7106 | 7595 | 7862 | **7521** | 7936 | 8351 | 8683 | **8323** | 7521 | 7973 | 8273 | **7922** |
| **$I_2N_3$** | 7147 | 8140 | 8623 | **7970** | 7994 | 8809 | 9149 | **8651** | 7571 | 8475 | 8886 | **8310** |
| **$I_2N_4$** | 7139 | 8179 | 8649 | **7989** | 7848 | 8850 | 9139 | **8612** | 7494 | 8515 | 8894 | **8301** |
| **Mean** | **6987** | **7482** | **7661** | **7376** | **7735** | **8086** | **8205** | **8009** | **7361** | **7784** | **7933** | **7692** |
| **$I_3N_1$** | 6525 | 5868 | 5291 | **5895** | 7196 | 6075 | 5657 | **6309** | 6861 | 5972 | 5474 | **6102** |
| **$I_3N_2$** | 7073 | 7621 | 7793 | **7496** | 7701 | 8350 | 8739 | **8263** | 7387 | 7986 | 8266 | **7880** |
| **$I_3N_3$** | 7102 | 8245 | 8545 | **7964** | 7887 | 8876 | 9239 | **8667** | 7495 | 8561 | 8892 | **8316** |
| **$I_3N_4$** | 7159 | 8280 | 8595 | **8011** | 7952 | 8929 | 9248 | **8710** | 7556 | 8605 | 8922 | **8361** |
| **Mean** | **6965** | **7504** | **7556** | **7341** | **7684** | **8058** | **8221** | **7987** | **7324** | **7781** | **7888** | **7664** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 6361 | 5873 | 5448 | **5894** | 6918 | 6182 | 5822 | **6308** | 6640 | 6028 | 5635 | **6101** |
| **N2** | 6775 | 7280 | 7473 | **7176** | 7372 | 7836 | 8132 | **7780** | 7073 | 7558 | 7803 | **7478** |
| **N3** | 6733 | 7489 | 7779 | **7334** | 7320 | 7930 | 8295 | **7848** | 7026 | 7709 | 8037 | **7591** |
| **N4** | 6747 | 7486 | 7777 | **7337** | 7299 | 7947 | 8258 | **7835** | 7023 | 7717 | 8017 | **7586** |
| **Mean** | **6654** | **7032** | **7120** | **6935** | **7227** | **7474** | **7627** | **7443** | **6941** | **7253** | **7373** | **7189** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | 26.86 | 105.44 | 27.31 | 107.20 | 19.15 | 62.45 |
| **Plant Density (P)** | 11.01 | 30.52 | 10.58 | 29.33 | 10.36 | 30.23 |
| **Nitrogen levels (N)** | 12.72 | 35.25 | 12.22 | 33.87 | 7.95 | 22.04 |
| **I X P** | 19.07 | 52.87 | 18.33 | 50.81 | 17.94 | 52.36 |
| **I X N** | 22.02 | 61.05 | 21.17 | 58.67 | 13.77 | 38.18 |
| **P X N** | 22.02 | 61.05 | 21.17 | 58.67 | 13.77 | 38.18 |
| **I X P X N** | 38.15 | 105.74 | 36.66 | 101.62 | 23.86 | 66.13 |

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$ Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$; $N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$; $N_4$ = 300 Kg ha$^{-1}$

Increase in plant density from $P_1$ to $P_3$ significantly increased the stover yield. Significantly higher stover yield (11469 kg $ha^{-l}$) was recorded at $P_3$ plant density (111111 plants $ha^{-1}$ ) as compared to others.

Stover yield differed significantly due to nitrogen levels. Increase in nitrogen level from $N_l$ to $N_3$ significantly increased the stover yield. Stover yield at $N_4$ was on par with $N_3$. Significantly higher stover yield of 10001 kg $ha^{-l}$ was recorded at $N_3$ (225 kg $ha^{-l}$).

The interaction effect of irrigation scheduling and plant density on stover yield was significant. Increase in irrigation from $I_1$ to $I_3$ accompanied with increase in plant density from $P_1$ to $P_3$ significantly increased the stover yield. Significantly higher stover yield of 12385 kg $ha^{-l}$ was recorded for irrigation scheduling at $I_3$ with plant density at $P_3$ over other interactions.

The irrigation scheduling and nitrogen levels combined effect (IxN) was significant. Increase in irrigation from $I_1$ to $I_3$ along with increase in nitrogen from $N_1$ to $N_3$ significantly increased the stover yield. Significantly higher stover yield of 10840 kg $ha^{-l}$ was recorded at $I_3$ (1.2 IW/CPE ratio) with $N_3$ (250 kg $ha^{-l}$) interaction over others.

Similarly, the interaction effect of plant density and nitrogen level had significant influence on stover yield. Increase in plant density from $P_1$ to $P_3$ accompanied with increase in nitrogen level from $N_l$ to $N_3$ significantly increased the stover yield. Plant density at $P_3$ (111111 plants $ha^{-l}$) coupled with nitrogen at $N_3$ (225 kg $ha^{-l}$) registered significantly higher stover yield of 12009 kg $ha^{-l}$.

The interaction effect of irrigation scheduling, plant density and nitrogen level was significant. The combination of irrigation at $I_3$ (1.2 IW/CPE ratio), plant density at $P_3$ (111111 plants $ha^{-1}$) and nitrogen level at $N_4$ (300 Kg $ha^{-l}$) recorded significantly superior stover yield (13251 kg $ha^{-l}$) over all other I x P x $N_4$ interactions except $I_3$ x $P_3$ X $N_4$ with which the stover yield (13223 kg $ha^{-l}$) was on par.

4.2.4.3 Total biomass yield (kg $ha^{-l}$) (cf. Table 27)

Biological yield or above ground total biomass was significantly influenced due to irrigation scheduling, plant density and nitrogen level. Similar trend was observed during both the years.

Irrigation scheduling effect observed over the seasons were significant. The total biomass yield increased significantly with increase in irrigation level from $I_1$ to $I_3$. The total biomass at $I_2$ (17811 kg $ha^{-l}$) was significantly higher, however on par with $I_3$ (17886 kg $ha^{-l}$).

Increase in plant density from $P_1$ to $P_3$ significantly increased the biomass yield. Plant density at $P_3$ (111111 plants $ha^{-l}$) recorded significantly higher biomass yield of 18842 kg $ha^{-l}$.

The biomass yield differed significantly due to nitrogen levels. Increase in nitrogen level from $N_1$ to $N_3$ significantly increased the total biomass yield, but increase from $N_3$ to $N_4$ was not significant. Maximum biomass yield of 17592 kg $ha^{-l}$ was recorded at $N_3$ (225 kg $ha^{-l}$) nitrogen level and was on par with $N_4$ (17563 kg $ha^{-l}$), however these were significantly higher than others.

The interaction effect due to irrigation scheduling and plant density was differed significantly. Increase in irrigation level from $I_1$ to $I_3$ with increase in plant density from $P_1$ to $P_3$ significantly increased the total biomass. Significantly higher total biomass yield of 20273 kg $ha^{-l}$ was recorded for irrigation scheduling at $I_3$ (1.2 IW/CPE ratio) coupled with plant density of $P_3$ (111111 plants $ha^{-l}$).

The interaction effect of irrigation scheduling and nitrogen levels were significant. Increase in irrigation level from $I_1$ to $I_3$ accompanied with increase in nitrogen level from $N_1$ to $N_3$ significantly increased the total biomass yield. Significantly higher biomass yield of 19156 kg $ha^{-1}$ was observed at $I_3$ irrigation scheduling (1.2 IW/CPE ratio) with nitrogen level of $N_3$ (225 kg $ha^{-1}$) and which was on par with $I_3$ x $N_4$ (19136 kg $ha^{-l}$)

The total biomass yield differed significantly due to plant density and nitrogen level interaction. At plant density of $P_1$, increase in nitrogen level from $N_1$ to $N_{2,}$ but at $P_2$ and $P_3$ increase in nitrogen level from $N_1$ to $N_3$ significantly increased the biomass yield. Further increase in nitrogen from $N_2$ to $N_4$ at $P_{1,}$ $N_3$ to $N_4$ at $P_2$ and $P_3$ plant densities recorded on par biomass yield. However among the N x P interactions, significantly higher total biomass yield

**Table 26. Stover yield (kg ha$^{-1}$) of maize as influenced by irrigation scheduling, plant density and nitrogen levels**

| Year | 1998-99 | | | | 1999-2000 | | | | Pooled | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** |
| **$I_1N_1$** | 6972 | 8916 | 9948 | **8612** | 6684 | 8259 | 8974 | **7972** | 6828 | 8588 | 9461 | **8292** |
| **$I_1N_2$** | 7158 | 9526 | 10864 | **9183** | 6764 | 8730 | 9965 | **8486** | 6961 | 9128 | 10415 | **8835** |
| **$I_1N_3$** | 7083 | 9169 | 10128 | **8793** | 6745 | 8507 | 9699 | **8317** | 6914 | 8838 | 9914 | **8555** |
| **$I_1N_4$** | 7147 | 9113 | 10030 | **8763** | 6724 | 8428 | 9591 | **8248** | 6936 | 8771 | 9811 | **8506** |
| **Mean** | **7090** | **9181** | **10243** | **8838** | **6729** | **8481** | **9557** | **8256** | **6910** | **8831** | **9900** | **8547** |
| **$I_2N_1$** | 6989 | 9350 | 10785 | **9041** | 6691 | 9247 | 10211 | **8716** | 6840 | 9299 | 10498 | **8879** |
| **$I_2N_2$** | 7797 | 11132 | 12703 | **10544** | 7791 | 10585 | 12010 | **10129** | 7794 | 10859 | 12357 | **10336** |
| **$I_2N_3$** | 7880 | 11418 | 13025 | **10774** | 7713 | 10859 | 12756 | **10443** | 7797 | 11139 | 12891 | **10609** |
| **$I_2N_4$** | 7903 | 11505 | 13053 | **10820** | 7795 | 11219 | 12434 | **10483** | 7849 | 11362 | 12744 | **10652** |
| **Mean** | **7642** | **10851** | **12392** | **10295** | **7498** | **10478** | **11853** | **9943** | **7570** | **10664** | **12122** | **10119** |
| **$I_3N_1$** | 6894 | 9280 | 10745 | **8973** | 6575 | 9191 | 10196 | **8654** | 6735 | 9236 | 10471 | **8814** |
| **$I_3N_2$** | 7797 | 11240 | 12956 | **10664** | 7748 | 10763 | 12235 | **10249** | 7773 | 11002 | 12596 | **10457** |
| **$I_3N_3$** | 7860 | 11541 | 13553 | **10985** | 7848 | 11345 | 12893 | **10695** | 7854 | 11443 | 13223 | **10840** |
| **$I_3N_4$** | 7971 | 10919 | 13565 | **10818** | 7884 | 11377 | 12937 | **10733** | 7928 | 11148 | 13251 | **10776** |
| **Mean** | **7631** | **10745** | **12705** | **10360** | **7514** | **10669** | **12065** | **10083** | **7572** | **10707** | 12385 | **10221** |
| **P X N Interaction** | P1 | P2 | P3 | **Mean** | P1 | P2 | P3 | **Mean** | P1 | P2 | P3 | **Mean** |
| **N1** | 6952 | 9182 | 10493 | **8875** | 6650 | 8899 | 9794 | **8448** | 6801 | 9041 | 10143 | **8662** |
| **N2** | 7584 | 10633 | 12174 | **10130** | 7434 | 10026 | 11403 | **9621** | 7509 | 10329 | 11789 | **9876** |
| **N3** | 7608 | 10709 | 12235 | **10184** | 7435 | 10237 | 11783 | **9818** | 7522 | 10473 | 12009 | **10001** |
| **N4** | 7674 | 10512 | 12216 | **10134** | 7468 | 10341 | 11654 | **9821** | 7571 | 10427 | 11935 | **9978** |
| **Mean** | **7454** | **10259** | **11780** | **9831** | **7247** | **9876** | **11158** | **9427** | **7351** | **10067** | **11469** | **9629** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | 21.37 | 83.91 | 23.00 | 90.31 | 15.70 | 51.20 |
| **Plant Density (P)** | 17.99 | 49.87 | 18.48 | 72.45 | 16.61 | 48.49 |
| **Nitrogen levels (N)** | 20.78 | 57.59 | 21.34 | 59.16 | 13.76 | 38.14 |
| **I X P** | 31.16 | 86.38 | 32.02 | 88.74 | 28.77 | 83.98 |
| **I X N** | 35.99 | 99.75 | 36.97 | 102.47 | 23.83 | 66.06 |
| **P X N** | 35.99 | 99.75 | 36.97 | 102.47 | 23.83 | 66.06 |
| **I X P X N** | 62.33 | 172.77 | 64.03 | 177.49 | 41.28 | 114.42 |

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.   Plant Density(P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$;$N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$;$N_4$ = 300 Kg ha$^{-1}$

**Table 27. Biomass yield ( kg ha$^{-1}$) of maize as influenced by irrigation scheduling, plant density and nitrogen levels**

| Year | 1998-99 | | | | 1999-2000 | | | | Pooled | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** |
| **$I_1N_1$** | 12977 | 14654 | 15492 | **14374** | 13080 | 14398 | 14936 | **14138** | 13029 | 14526 | 15214 | **14256** |
| **$I_1N_2$** | 13304 | 16151 | 17629 | **15695** | 13242 | 15536 | 16939 | **15239** | 13273 | 15844 | 17284 | **15467** |
| **$I_1N_3$** | 13032 | 15250 | 16298 | **14860** | 12824 | 14612 | 16196 | **14544** | 12928 | 14931 | 16247 | **14702** |
| **$I_1N_4$** | 13090 | 15111 | 16117 | **14773** | 12821 | 14491 | 15977 | **14430** | 12956 | 14801 | 16047 | **14601** |
| **Mean** | **13101** | **15292** | **16384** | **14925** | **12992** | **14759** | **16012** | **14588** | **13046** | **15025** | **16198** | **14757** |
| **$I_2N_1$** | 13543 | 15363 | 16295 | **15067** | 13853 | 15580 | 16059 | **15164** | 13698 | 15472 | 16177 | **15116** |
| **$I_2N_2$** | 14903 | 18727 | 20565 | **18065** | 15727 | 18936 | 20693 | **18452** | 15315 | 18832 | 20629 | **18259** |
| **$I_2N_3$** | 15027 | 19558 | 21648 | **18744** | 15707 | 19668 | 21905 | **19093** | 15367 | 19613 | 21777 | **18919** |
| **$I_2N_4$** | 15042 | 19684 | 21702 | **18809** | 15643 | 20069 | 21573 | **19095** | 15343 | 19877 | 21638 | **18952** |
| **Mean** | **14629** | **18333** | **20053** | **17671** | **15233** | **18563** | **20058** | **17951** | **14931** | **18448** | **20055** | **17811** |
| **$I_3N_1$** | 13419 | 15148 | 16036 | **14868** | 13771 | 15266 | 15853 | **14963** | 13595 | 15207 | 15945 | **14916** |
| **$I_3N_2$** | 14870 | 18861 | 20749 | **18160** | 15449 | 19113 | 20974 | **18512** | 15160 | 18987 | 20862 | **18336** |
| **$I_3N_3$** | 14962 | 19786 | 22098 | **18949** | 15735 | 20221 | 22132 | **19363** | 15349 | 20004 | 22115 | **19156** |
| **$I_3N_4$** | 15130 | 19199 | 22160 | **18830** | 15836 | 20306 | 22185 | **19442** | 15483 | 19753 | 22173 | **19136** |
| **Mean** | **14595** | **18249** | **20261** | **17702** | **15198** | **18727** | **20286** | **18070** | **14897** | **18488** | **20273** | **17886** |
| **NXP Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **N1** | 13313 | 15055 | 15941 | **14770** | 13568 | 15081 | 15616 | **14755** | 13441 | 15068 | 15779 | **14762** |
| **N2** | 14359 | 17913 | 19648 | **17307** | 14806 | 17862 | 19535 | **17401** | 14583 | 17887 | 19592 | **17354** |
| **N3** | 14340 | 18198 | 20015 | **17518** | 14755 | 18167 | 20078 | **17667** | 14548 | 18183 | 20046 | **17592** |
| **N4** | 14421 | 17998 | 19993 | **17471** | 14767 | 18289 | 19912 | **17656** | 14594 | 18143 | 19952 | **17563** |
| **Mean** | **14108** | **17291** | **18899** | **16766** | **14474** | **17350** | **18785** | **16870** | **14291** | **17320** | **18842** | **16818** |

| | **1998-99** | | **1999-2000** | | **Pooled** | |
|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | 50.95 | 200.04 | 44.51 | 174.73 | 33.83 | 110.32 |
| **Plant Density (P)** | 23.01 | 63.79 | 22.00 | 86.22 | 20.06 | 58.57 |
| **Nitrogen levels (N)** | 26.57 | 73.65 | 25.40 | 70.40 | 17.13 | 47.49 |
| **I X P** | 39.86 | 110.48 | 38.10 | 105.60 | 34.75 | 101.44 |
| **I X N** | 46.02 | 127.57 | 43.99 | 121.94 | 29.68 | 82.26 |
| **P X N** | 46.02 | 127.57 | 43.99 | 121.94 | 29.68 | 82.26 |
| **I X P X N** | 79.72 | 220.96 | 76.20 | 211.21 | 51.40 | 142.48 |

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$;$N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$;$N_4$ = 300 Kg ha$^{-1}$

The interaction effect due to irrigation scheduling, plant density and nitrogen level (IxPxN) was significant. The increase in irrigation scheduling from $I_1$ to $I_3$ with increase in plant density from $P_1$to $P_3$ and nitrogen level from $N_1$ to $N_3$ significantly increased the biomass yield. Significantly higher biomass yield of 22173 kg $ha^{-l}$ was registered for irrigation scheduling at $I_3$ combined with plant density at $P_3$ and nitrogen level at $N_4$ over other interactions except $I_3xP_3xN_3$ (22115 kg $ha^{-l}$) and these interactions recorded on par biomass yield.

4.2.4.4 Harvest index (cf. Table 28)

Harvest index significantly influenced due to irrigation scheduling, plant density and nitrogen level during both the years. When averaged over the two years, increase in irrigation from $I_1$ to $I_2$ significantly increased the harvest index and recorded maximum of 0.436 at $I_2$ (0.9 IW/CPE ratio) than other irrigation levels.

Increase in plant density from $P_1$to $P_3$ significantly reduced the harvest index. Significantly higher harvest index of 0.485 was recorded at $P_1$ plant density.

Increase in nitrogen from $N_1$ to $N_2$ increased the harvest index from 0.417 to 0.435. However, recorded statistically on par at $N_2$, $N_3$ and $N_4$ nitrogen levels.

The interaction effect of irrigation scheduling and plant density influenced harvest index significantly. Increase in irrigation level from $I_1$ to $I_2$ at same level of plant density significantly increased the harvest index. Increasing plant density from $P_1$ to $P_3$ at same level of irrigation significantly decreased the harvest index. However, significantly higher harvest index of 0.493 was recorded at $I_2$ with plant density at $P_1$ which was on par with $I_3xP_1$ (0.492) and significantly higher than other interactions.

Increase in irrigation level from $I_1$ to $I_2$ significantly increased the harvest index at higher level of nitrogen namely $N_2$ to $N_4$, while at lower level of nitrogen namely $N_1$ harvest index decreased. Significantly higher harvest index of 0.444 was registered in irrigation scheduling at $I_2$ with $N_3$, which is on par with $I_2$ x $N_4$ (0.443) and $I_3xN_4$ (0.442) and however significantly higher over other combinations.

Plant density and nitrogen interaction effect on harvest index was significant. Increase in plant density at same level of nitrogen decreased the harvest index. Increase in nitrogen level at $P_1$ did not influence harvest index, but at $P_2$ and $P_3$ plant densities increase in nitrogen significantly increased the harvest index. However, significantly higher harvest index of 0.494 was recorded at $P_1$ x $N_1$ interaction as compared to other treatment combinations.

Further, interaction effect due to irrigation scheduling, plant density and nitrogen level differed significantly. The higher harvest index of 0.505 was recorded at $I_3$ x $P_1$ X $N_1$ interaction which was on par with $I_2XP_1XN_1$ (0.501) and significantly higher than other interaction effects.

4.2.4.5 Grain weight (g $grain^{-1}$) (cf. Table 29)

Grain weight differed significantly due to irrigation scheduling during both the years. Irrigation scheduling from $I_1$ to $I_2$ significantly increased the grain weight and recorded significantly higher grain weight at $I_3$ (0.290 g $grain^{-1}$) over $I_1$, however which was on par with $I_2$ (0.288 g $grain^{-1}$).

Increase in plant density from $P_1$ to $P_3$ caused reduction in grain weight, however the effect was non significant. The higher and lower grain weight was recorded for $P_1$ (0.279 g $grain^{-1}$) and $P_3$ (0.273 g $grain^{-1}$) respectively.

The effect of nitrogen level on grain weight was not significant, during both the years.

The interaction effect due to irrigation and plant density had significant influence on grain weight. Increase in irrigation from $I_1$ to $I_2$ at same level of plant density significantly increased the grain weight. While increase in plant density at same level of irrigation reduced the grain weight. The highest grain weight of 0.293 g $grain^{-l}$ was obtained at $I_3$ x $P_l$ which was on par with $I_3$ X $P_2$ (0.291 g $grain^{-1}$), $I_2$ X $P_1$ (0.290 g $grain^{-1}$), $I_2$ X $P_2$ (0.287 g $grain^{-1}$), $I_3$ x $P_3$ (0.288 g $grain^{-1}$) and $I_2$ x $P_3$ (0.286 g $grain^{-1}$) and were significantly higher than remaining treatment combinations.

**Table 28. Harvest index of maize as influenced by irrigation scheduling, plant density and nitrogen levels**

| Year | 1998-99 | | | | 1999-2000 | | | | Pooled | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** |
| **$I_1N_1$** | 0.463 | 0.392 | 0.358 | **0.404** | 0.489 | 0.426 | 0.399 | **0.438** | 0.476 | 0.409 | 0.378 | **0.421** |
| **$I_1N_2$** | 0.462 | 0.410 | 0.384 | **0.419** | 0.489 | 0.438 | 0.412 | **0.446** | 0.476 | 0.424 | 0.397 | **0.432** |
| **$I_1N_3$** | 0.456 | 0.399 | 0.379 | **0.411** | 0.474 | 0.418 | 0.401 | **0.431** | 0.465 | 0.408 | 0.390 | **0.421** |
| **$I_1N_4$** | 0.454 | 0.397 | 0.378 | **0.410** | 0.476 | 0.418 | 0.400 | **0.431** | 0.465 | 0.407 | 0.389 | **0.420** |
| **Mean** | **0.459** | **0.399** | **0.374** | **0.411** | **0.482** | **0.425** | **0.403** | **0.437** | **0.470** | **0.412** | **0.389** | **0.424** |
| **$I_2N_1$** | 0.484 | 0.391 | 0.338 | **0.404** | 0.517 | 0.406 | 0.364 | **0.429** | 0.501 | 0.399 | 0.351 | **0.417** |
| **$I_2N_2$** | 0.477 | 0.406 | 0.382 | **0.422** | 0.505 | 0.441 | 0.420 | **0.455** | 0.491 | 0.423 | 0.401 | **0.438** |
| **$I_2N_3$** | 0.476 | 0.416 | 0.398 | **0.430** | 0.509 | 0.448 | 0.418 | **0.458** | 0.493 | 0.432 | 0.408 | **0.444** |
| **$I_2N_4$** | 0.475 | 0.416 | 0.399 | **0.430** | 0.502 | 0.441 | 0.424 | **0.455** | 0.488 | 0.428 | 0.411 | **0.443** |
| **Mean** | **0.478** | **0.407** | **0.379** | **0.421** | **0.508** | **0.434** | **0.406** | **0.449** | **0.493** | **0.421** | **0.393** | **0.436** |
| **$I_3N_1$** | 0.486 | 0.387 | 0.330 | **0.401** | 0.523 | 0.398 | 0.357 | **0.426** | 0.505 | 0.393 | 0.343 | **0.414** |
| **$I_3N_2$** | 0.476 | 0.404 | 0.376 | **0.418** | 0.498 | 0.437 | 0.417 | **0.451** | 0.487 | 0.421 | 0.396 | **0.435** |
| **$I_3N_3$** | 0.475 | 0.417 | 0.387 | **0.426** | 0.501 | 0.439 | 0.417 | **0.453** | 0.488 | 0.428 | 0.402 | **0.439** |
| **$I_3N_4$** | 0.473 | 0.431 | 0.388 | **0.431** | 0.502 | 0.440 | 0.417 | **0.453** | 0.488 | 0.436 | 0.402 | **0.442** |
| **Mean** | **0.477** | **0.410** | **0.370** | **0.419** | **0.506** | **0.428** | **0.402** | **0.445** | **0.492** | **0.419** | **0.386** | **0.432** |
| **P X N Interaction** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** |
| **N1** | 0.478 | 0.390 | 0.342 | **0.403** | 0.510 | 0.410 | 0.373 | **0.431** | 0.494 | 0.400 | 0.358 | **0.417** |
| **N2** | 0.471 | 0.407 | 0.381 | **0.420** | 0.497 | 0.439 | 0.416 | **0.451** | 0.485 | 0.423 | 0.398 | **0.435** |
| **N3** | 0.469 | 0.411 | 0.388 | **0.422** | 0.495 | 0.435 | 0.412 | **0.447** | 0.482 | 0.423 | 0.400 | **0.435** |
| **N4** | 0.467 | 0.415 | 0.388 | **0.423** | 0.493 | 0.433 | 0.413 | **0.447** | 0.480 | 0.424 | 0.401 | **0.435** |
| **Mean** | **0.471** | **0.405** | **0.375** | **0.417** | **0.499** | **0.429** | **0.404** | **0.444** | **0.485** | **0.417** | **0.389** | **0.431** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Irrigation (I)** | 0.0006 | 0.0024 | 0.0007 | 0.0029 | 0.0004 | 0.0012 |
| **Plant Density (P)** | 0.0004 | 0.0011 | 0.0007 | 0.0030 | 0.0004 | 0.0011 |
| **Nitrogen levels (N)** | 0.0004 | 0.0011 | 0.0009 | 0.0025 | 0.0005 | 0.0013 |
| **I X P** | 0.0006 | 0.0017 | 0.0013 | 0.0037 | 0.0007 | 0.0019 |
| **I X N** | 0.0007 | 0.0019 | 0.0015 | 0.0043 | 0.0008 | 0.0022 |
| **P X N** | 0.0007 | 0.0019 | 0.0015 | 0.0043 | 0.0008 | 0.0022 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **I X P X N** | 0.0012 | 0.0033 | 0.0027 | 0.0074 | 0.0014 | 0.0038 |

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio. Plant Density(P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$;$N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$;$N_4$ = 300 Kg ha$^{-1}$

Irrigation scheduling and nitrogen level interaction effect (IxN) differed significantly. The increase in nitrogen level beyond $N_2$ at $I_1$ decreased the grain weight, however increase in nitrogen from $N_1$ to $N_3$ at $I_2$ and $I_3$ irrigation scheduling increased the grain weight.

Due to interaction of plant density and nitrogen level the grain weight was not significant. Increase in nitrogen from $N_1$ to $N_2$ at $P_1$ plant density, and from $N_1$ to $N_3$ at $P_2$ and $P_3$ plant densities increased the grain weight.

The interaction effects due to irrigation scheduling, plant density and nitrogen levels were found to be significant. Higher grain weight of 0.299 g. grain$^{-1}$ was observed at $I_3$ x $P_2$ X $N_3$ and $I_2$ x $P_1$ X $N_3$ combinations.

4.2.4.6 Grains ear$^{-l}$ (cf. Table 30)

Grains ear$^{-1}$ differed significantly due to irrigation scheduling, plant. density and nitrogen levels during both the years. When averaged over two years, increase in irrigation level from $I_1$ to $I_2$ significantly increased the grains ear$^{-1}$. Further increase in irrigation from $I_2$ to $I_3$ was not significant. Higher grains ear$^{-1}$ (355 grains) was obtained at $I_3$ (1.2 IW / CPE ratio) and $I_2$ (350 grains) were on par and which were significantly higher over $I_1$ (333 grains).

Increase in the level of plant density from $P_1$ to $P_3$ significantly reduced the grains ear$^{-1}$. Significantly higher (473 grains) and lower (250 grains) grains ear$^{-1}$ were obtained at $P_1$ (55555 plants ha$^{-1}$) and $P_3$ (111111 plants ha$^{-1}$) respectively.

Increase in nitrogen level from $N_1$ to $N_3$ increased the grains ear$^{-1}$. Significantly higher grains ear$^{-1}$ (361 grains) were recorded at $N_3$ over $N_1$, and was on par with $N_2$ (356 grains) and $N_4$ (360 grains).

The interaction effect of irrigation scheduling and plant density was significant. Increase in irrigation scheduling from $I_1$ to $I_2$ at same level of plant density increased the grains ear$^{-1}$. Increase in plant density from $P_1$to $P_3$ at same level of irrigation significantly reduced the grains ear$^{-1}$.. However, significantly maximum grains ear$^{-1}$ (482 grains) were registered in irrigation at $I_2$ (0.9 IW /CPE ratio) coupled with plant density at $P_1$ (55555 plants ha$^{-1}$).

Increase in irrigation level from $I_1$ to $I_3$ accompanied with increase in nitrogen level from $N_1$ to $N_3$ significantly increased the grains ear$^{-1}$ Significantly higher grains ear$^{-1}$ (383 grains) obtained in $I_3$ x $N_3$ treatment combination over others except in $I_2$ x $N_3$ (367 grains), $I_3$ x $N_4$ (380 grains) and $I_2$ x $N_4$ (370 grains) with which grains ear$^{-1}$ were on par.

The interaction of plant density and nitrogen differed significantly. Increase in nitrogen level from $N_1$ to $N_2$ at $P_1$ plant density, from $N_1$ to $N_3$ at $P_2$ and $P_3$ plant densities increased the grains ear$^{-1}$. Further increase in nitrogen beyond $N_2$ at $P_1$, and $N_3$ at $P_2$ and $P_3$ recorded on par grains ear$^{-1}$.

The interaction effect due to irrigation scheduling, plant density and nitrogen level differed significantly. Increase in irrigation level from $I_1$ to $I_2$ coupled with increase in nitrogen level from $N_1$ to $N_2$ at $P_1$ plant density, and $N_1$ to $N_3$ at $P_2$ and $P_3$ plant densities increased the grains ear$^{-1}$ and further increase in nitrogen from $N_2$ to $N_3$ at $P_1$, and $N_3$ to $N_4$ at $P_2$ and $P_3$ recorded statistically on par grains ear$^{-1}$.

4.2.4.7 Grain number m$^{-2}$ (cf. Table 31)

Grain number m$^{-2}$ differed significantly due to irrigation scheduling, plant density and nitrogen level during both the seasons.

An average over two years, increase in irrigation level from $I_1$ to $I_2$ significantly increased the grain number m$^{-2}$ and recorded significantly higher (2788 grains) grain number m$^{-2}$ for $I_2$ (0.9 IW /CPE ratio). Irrigation scheduling at $I_2$ and $I_3$ recorded statistically on par grain number m$^{-2}$.

Increase in plant density from $P_1$ to $P_3$ caused significant increase in grain number m$^{-2}$. Significantly higher (2803 grains) and lower (2607 grains) grain number m$^{-2}$ were recorded in $P_3$ and $P_1$ respectively,

Table 29. Grain weight (g $grain^{-1}$) of maize as influenced by irrigation scheduling, plant density and nitrogen levels

| Year | 1998-99 | | | | 1999-2000 | | | | Pooled | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** |
| **$I_1N_1$** | 0.261 | 0.254 | 0.254 | **0.256** | 0.258 | 0.257 | 0.256 | **0.257** | 0.260 | 0.256 | 0.255 | **0.257** |
| **$I_1N_2$** | 0.267 | 0.255 | 0.255 | **0.259** | 0.259 | 0.259 | 0.258 | **0.259** | 0.263 | 0.257 | 0.257 | **0.259** |
| **$I_1N_3$** | 0.251 | 0.240 | 0.234 | **0.242** | 0.244 | 0.242 | 0.235 | **0.240** | 0.248 | 0.241 | 0.235 | **0.241** |
| **$I_1N_4$** | 0.251 | 0.240 | 0.230 | **0.240** | 0.244 | 0.240 | 0.234 | **0.239** | 0.248 | 0.240 | 0.232 | **0.240** |
| **Mean** | **0.258** | **0.247** | **0.243** | **0.249** | **0.251** | **0.250** | **0.246** | **0.249** | **0.254** | **0.248** | **0.245** | **0.249** |
| **$I_2N_1$** | 0.274 | 0.274 | 0.274 | **0.274** | 0.283 | 0.286 | 0.285 | **0.285** | 0.279 | 0.280 | 0.280 | **0.279** |
| **$I_2N_2$** | 0.284 | 0.274 | 0.274 | **0.277** | 0.292 | 0.288 | 0.286 | **0.289** | 0.288 | 0.281 | 0.280 | **0.283** |
| **$I_2N_3$** | 0.287 | 0.283 | 0.282 | **0.284** | 0.305 | 0.299 | 0.298 | **0.301** | 0.296 | 0.291 | 0.290 | **0.292** |
| **$I_2N_4$** | 0.287 | 0.287 | 0.285 | **0.286** | 0.306 | 0.304 | 0.303 | **0.304** | 0.297 | 0.296 | 0.294 | **0.295** |
| **Mean** | **0.283** | **0.280** | **0.279** | **0.280** | **0.297** | **0.294** | **0.293** | **0.295** | **0.290** | **0.287** | **0.286** | **0.288** |
| **$I_3N_1$** | 0.274 | 0.274 | 0.274 | **0.274** | 0.287 | 0.285 | 0.286 | **0.286** | 0.281 | 0.280 | 0.280 | **0.280** |
| **$I_3N_2$** | 0.288 | 0.284 | 0.281 | **0.284** | 0.292 | 0.289 | 0.286 | **0.289** | 0.290 | 0.287 | 0.284 | **0.287** |
| **$I_3N_3$** | 0.296 | 0.290 | 0.289 | **0.292** | 0.305 | 0.304 | 0.302 | **0.304** | 0.301 | 0.297 | 0.296 | **0.298** |
| **$I_3N_4$** | 0.293 | 0.292 | 0.286 | **0.290** | 0.305 | 0.306 | 0.303 | **0.305** | 0.299 | 0.299 | 0.295 | **0.298** |
| **Mean** | **0.288** | **0.285** | **0.283** | **0.285** | **0.297** | **0.296** | **0.294** | **0.296** | **0.293** | **0.291** | **0.288** | **0.290** |
| **P X N Interaction** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** |
| **N1** | 0.270 | 0.267 | 0.267 | **0.268** | 0.276 | 0.276 | 0.276 | **0.276** | 0.273 | 0.272 | 0.272 | **0.272** |
| **N2** | 0.280 | 0.271 | 0.270 | **0.274** | 0.281 | 0.279 | 0.277 | **0.279** | 0.280 | 0.275 | 0.273 | **0.276** |
| **N3** | 0.278 | 0.271 | 0.268 | **0.272** | 0.285 | 0.282 | 0.278 | **0.282** | 0.281 | 0.276 | 0.273 | **0.277** |
| **N4** | 0.277 | 0.273 | 0.267 | **0.272** | 0.285 | 0.283 | 0.280 | **0.283** | 0.281 | 0.278 | 0.274 | **0.278** |
| **Mean** | **0.276** | **0.271** | **0.268** | **0.272** | **0.282** | **0.280** | **0.278** | **0.280** | **0.279** | **0.275** | **0.273** | **0.276** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Irrigation (I)** | 0.0010 | 0.0041 | 0.0006 | 0.0024 | 0.0052 | 0.0170 |
| **Plant Density (P)** | 0.0093 | 0.0026 | 0.0004 | 0.0016 | 0.0046 | 0.0134 |
| **Nitrogen levels (N)** | 0.0011 | 0.0030 | 0.0004 | 0.0011 | 0.0054 | 0.0150 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **I X P** | 0.0016 | 0.0045 | 0.0006 | 0.0017 | 0.0080 | 0.0234 |
| **I X N** | 0.0019 | 0.0052 | 0.0007 | 0.0019 | 0.0094 | 0.0261 |
| **P X N** | 0.0019 | 0.0052 | 0.0007 | 0.0019 | 0.0094 | 0.0261 |
| **I X P X N** | 0.0032 | 0.0090 | 0.0013 | 0.0036 | 0.0162 | 0.0449 |

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.
Plant Density(P) : $P_1$ = 55555 Plants $ha^{-1}$; $P_2$ = 83333 Plants $ha^{-1}$; $P_3$ = 111111 Plants $ha^{-1}$
Nitrogen levels (N) : $N_1$ = 75 Kg $ha^{-1}$;$N_2$ = 150 Kg $ha^{-1}$; $N_3$ = 225 Kg $ha^{-1}$;$N_4$ = 300 Kg $ha^{-1}$

**Table 30. Grains ear$^{-1}$ of maize as influenced by irrigation scheduling, plant density and nitrogen levels**

| Year | 1998-99 | | | | 1999-2000 | | | | Pooled | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** |
| **$I_1N_1$** | 435 | 276 | 198 | **303** | 465 | 294 | 211 | **323** | 450 | 285 | 205 | **313** |
| **$I_1N_2$** | 451 | 319 | 253 | **341** | 486 | 334 | 270 | **363** | 469 | 327 | 262 | **352** |
| **$I_1N_3$** | 451 | 307 | 226 | **328** | 466 | 313 | 245 | **341** | 459 | 310 | 236 | **335** |
| **$I_1N_4$** | 451 | 303 | 221 | **325** | 466 | 302 | 242 | **337** | 459 | 303 | 232 | **331** |
| **Mean** | **447** | **301** | **225** | **324** | **471** | **311** | **242** | **341** | **459** | **306** | **233** | **333** |
| **$I_2N_1$** | 448 | 268 | 184 | **300** | 474 | 272 | 189 | **312** | 461 | 270 | 187 | **306** |
| **$I_2N_2$** | 467 | 273 | 266 | **335** | 494 | 362 | 279 | **378** | 481 | 318 | 273 | **357** |
| **$I_2N_3$** | 473 | 262 | 280 | **338** | 505 | 383 | 299 | **396** | 489 | 323 | 290 | **367** |
| **$I_2N_4$** | 476 | 263 | 281 | **340** | 515 | 383 | 299 | **399** | 496 | 323 | 290 | **370** |
| **Mean** | **466** | **267** | **253** | **328** | **497** | **350** | **267** | **371** | **482** | **308** | **260** | **350** |
| **$I_3N_1$** | 446 | 263 | 178 | **296** | 473 | 262 | 180 | **305** | 460 | 263 | 179 | **300** |
| **$I_3N_2$** | 465 | 276 | 265 | **335** | 496 | 364 | 279 | **380** | 481 | 320 | 272 | **358** |
| **$I_3N_3$** | 475 | 361 | 282 | **373** | 501 | 382 | 295 | **393** | 488 | 372 | 289 | **383** |
| **$I_3N_4$** | 483 | 352 | 283 | **373** | 486 | 382 | 296 | **388** | 485 | 367 | 290 | **380** |
| **Mean** | **467** | **313** | **252** | **344** | **489** | **348** | **263** | **366** | **478** | **330** | **257** | **355** |
| **NXP Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 443 | 269 | 187 | **300** | 471 | 276 | 193 | **313** | 457 | 273 | 190 | **306** |
| **N2** | 461 | 289 | 261 | **337** | 492 | 353 | 276 | **374** | 477 | 321 | 269 | **356** |
| **N3** | 466 | 310 | 263 | **346** | 491 | 359 | 280 | **377** | 479 | 335 | 271 | **361** |
| **N4** | 470 | 306 | 262 | **346** | 489 | 356 | 279 | **375** | 480 | 331 | 270 | **360** |
| **Mean** | **460** | **294** | **243** | **332** | **486** | **336** | **257** | **360** | **473** | **315** | **250** | **346** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing Means** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | 6.36 | 24.96 | 0.71 | 2.79 | 3.20 | 10.43 |
| **Plant Population (P)** | 6.36 | 24.96 | 0.71 | 2.79 | 3.12 | 9.09 |
| **Nitrogen levels (N)** | 6.74 | 18.68 | 2.81 | 7.78 | 3.66 | 10.15 |
| **I X P** | 10.11 | 28.02 | 4.21 | 11.67 | 5.40 | 15.75 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **I X N** | 11.67 | 32.36 | 4.86 | 13.47 | 6.34 | 17.58 |
| **P X N** | 11.67 | 32.36 | 4.86 | 13.47 | 6.34 | 17.58 |
| **I X P X N** | 20.22 | 56.04 | 8.42 | 23.33 | 10.99 | 30.45 |

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants $ha^{-1}$; $P_2$ = 83333 Plants $ha^{-1}$; $P_3$ = 111111 Plants $ha^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg $ha^{-1}$;$N_2$ = 150 Kg $ha^{-1}$; $N_3$ = 225 Kg $ha^{-1}$;$N_4$ = 300 Kg $ha^{-1}$

**Table 31. Grain number m$^{-2}$ of maize as influenced by irrigation scheduling , plant density and nitrogen levels**

| Year | 1998-99 | | | | 1999-2000 | | | | Pooled | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 2387 | 2306 | 2197 | **2297** | 2555 | 2442 | 2358 | **2452** | 2471 | 2374 | 2278 | **2374** |
| $I_1N_2$ | 2502 | 2632 | 2816 | **2650** | 2674 | 2788 | 2991 | **2818** | 2588 | 2710 | 2904 | **2734** |
| $I_1N_3$ | 2492 | 2563 | 2695 | **2583** | 2612 | 2633 | 2770 | **2672** | 2552 | 2598 | 2733 | **2628** |
| $I_1N_4$ | 2483 | 2420 | 2669 | **2524** | 2555 | 2596 | 2732 | **2628** | 2519 | 2508 | 2701 | **2576** |
| **Mean** | **2466** | **2480** | **2594** | **2514** | **2599** | **2615** | **2713** | **2642** | **2533** | **2548** | **2654** | **2578** |
| $I_2N_1$ | 2457 | 2230 | 2053 | **2247** | 2607 | 2260 | 2097 | **2321** | 2532 | 2245 | 2075 | **2284** |
| $I_2N_2$ | 2573 | 2816 | 2954 | **2781** | 2717 | 3002 | 3107 | **2942** | 2645 | 2909 | 3031 | **2862** |
| $I_2N_3$ | 2630 | 2989 | 3118 | **2912** | 2830 | 3149 | 3303 | **3094** | 2730 | 3069 | 3211 | **3003** |
| $I_2N_4$ | 2641 | 2996 | 3235 | **2957** | 2692 | 3152 | 3315 | **3053** | 2667 | 3074 | 3275 | **3005** |
| **Mean** | **2575** | **2758** | **2840** | **2724** | **2712** | **2891** | **2956** | **2853** | **2643** | **2824** | **2898** | **2788** |
| $I_3N_1$ | 2453 | 2184 | 1978 | **2205** | 2602 | 2181 | 2004 | **2262** | 2528 | 2183 | 1991 | **2234** |
| $I_3N_2$ | 2578 | 2689 | 2936 | **2734** | 2730 | 3019 | 3107 | **2952** | 2654 | 2854 | 3022 | **2843** |
| $I_3N_3$ | 2624 | 2921 | 3100 | **2882** | 2740 | 3229 | 3311 | **3093** | 2682 | 3075 | 3206 | **2988** |
| $I_3N_4$ | 2660 | 3013 | 3111 | **2928** | 2765 | 3235 | 3326 | **3109** | 2713 | 3124 | 3219 | **3018** |
| **Mean** | **2579** | **2702** | **2781** | **2687** | **2709** | **2916** | **2937** | **2854** | **2644** | **2809** | **2859** | **2771** |
| **NXP Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 2432 | 2240 | 2076 | **2249** | 2588 | 2294 | 2153 | **2345** | 2510 | 2267 | 2115 | **2297** |
| **N2** | 2551 | 2712 | 2902 | **2722** | 2707 | 2936 | 3068 | **2904** | 2629 | 2824 | 2985 | **2813** |
| **N3** | 2582 | 2824 | 2971 | **2792** | 2727 | 3004 | 3128 | **2953** | 2655 | 2914 | 3050 | **2873** |
| **N4** | 2595 | 2810 | 3005 | **2803** | 2671 | 2994 | 3124 | **2930** | 2633 | 2902 | 3065 | **2866** |
| **Mean** | **2540** | **2647** | **2739** | **2642** | **2673** | **2807** | **2868** | **2783** | **2607** | **2727** | **2803** | **2712** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | 5.35 | 20.99 | 17.55 | 68.91 | 9.17 | 29.92 |
| **Plant Population (P)** | 9.04 | 25.06 | 12.87 | 35.44 | 10.11 | 29.50 |
| **Nitrogen levels (N)** | 10.44 | 28.94 | 14.85 | 41.18 | 8.40 | 23.27 |
| **I X P** | 15.65 | 43.41 | 22.28 | 61.77 | 17.51 | 51.10 |
| **I X N** | 18.08 | 50.12 | 25.73 | 71.33 | 14.54 | 40.30 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **P X N** | 18.08 | 50.12 | 25.73 | 71.33 | 14.54 | 40.30 |
| **I X P X N** | 31.32 | 86.81 | 44.57 | 123.55 | 25.19 | 69.81 |

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$;$N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$;$N_4$ = 300 Kg ha$^{-1}$

Significant differences were observed due to increase in nitrogen level. Increase in nitrogen from $N_1$ to $N_3$ increased the grain number $m^{-2}$, however $N_3$ and $N_4$ recorded on par grain number $m^{-2}$. Higher grain number $m^{-2}$ (2873 grains) recorded at $N_3$ and $N_4$ (2866 grains) were on par and significantly higher over other nitrogen levels.

The interaction effect of irrigation scheduling and plant density was significant. Increase in irrigation level from $I_1$ to $I_2$ with increase in plant density from $P_1$ to $P_3$ significantly increased the grain number $m^{-2}$. Significantly higher grain number $m^{-2}$ (2898 grains) was recorded for $I_2$ (0.9 IW/*CPE* ratio) coupled with $P_3$ (111111 plants $ha^{-l}$) over other combinations except $I_3$ x $P_3$ (2859 grains) these were on par.

The increase in irrigation scheduling from $I_1$ to $I_2$ accompanied with increase in nitrogen level from $N_1$ to $N_3$ significantly increased the grain number $m^{-2}$. Significantly higher grain number $m^{-2}$ (3018 grains) was recorded at $I_3$ (1.2 IW/*CPE* ratio) coupled with $N_4$ (225 kg $ha^{-l}$). This was statistically on par with $I_2$ x $N_4$ (3005 grains), $I_2$ X $N_3$ (3003 grains) and $I_3$ x $N_3$ (2988 grains) interactions.

Interaction effect of plant density and nitrogen level was significant. Increase in plant density from $P_1$ to $P_3$ coupled with increase in nitrogen level from $N_l$ to $N_4$ differed significantly with respect to grain number $m^{-2}$. Increase in nitrogen level upto $N_2$ at $P_1$, and upto $N_3$ at $P_2$ and $P_3$ plant densities significantly increased the grain number $m^{-2}$. However, significantly higher grain number $m^{-2}$ (3065 grains) was recorded for plant density at $P_3$ (111111 plants $ha^{-1}$) with nitrogen level at $N_4$ (300 kg $ha^{-l}$). This was statistically on par with $P_3$ x $N_3$ (3050 grains) treatment combination.

The interaction effect of irrigation scheduling, plant density and nitrogen levels differed significantly for grain number $m^{-2}$. Increase in plant density from $P_1$ to $P_3$ coupled with increase in irrigation level from $I_1$ to $I_2$ and nitrogen level from $N_l$ to $N_4$ increased the grain number $m^{-2}$ except at $N_l$, wherein increase of plant density from $P_1$ to $P_3$ significantly reduced the grain number $m^{-2}$. Higher grain number $m^{-2}$ (3275 grains) was recorded for irrigation at $I_2$ (1.2 IW /CPE ratio) coupled with plant density of $P_3$ (111111 plants $ha^{-l}$) and nitrogen level of $N_4$ (300 kg $ha^{-l}$). This was statistically on par with $I_3$ x $P_3$ X $N_4$ (3219 grains) and $1_2$ x $P_3$ X $N_3$ (3211 grains) treatment combinations.

### 4.2.5 Water use and water use efficiency

#### 4.2.5.1 Water use (mm) (cf. Table 32)

The water use by maize crop differed significantly due to irrigation scheduling, plant density and nitrogen levels during both the years. The trend in water use was similar during 1998-99 and 1999-2000 cropping seasons.

Over the seasons, increase in irrigation scheduling from $I_1$ (0.6 IW/CPE ratio) to $I_3$ (1.20 IW/CPE ratio) through $I_2$ (0.9 IW/CPE ratio) significantly increased the water use. The water use was 392.24, 477.37 and 484.64 mm for $I_1$, $I_2$ and $I_3$ respectively.

The increase in plant density from $P_1$ to $P_3$ significantly increased the water use. The water use for $P_l$, $P_2$ and $P_3$ was 445.70, 452.83 and 455.73 mm respectively.

The increase in nitrogen level from $N_l$ to $N_2$ significantly increased the water use from 450.93 to 456.67 mm, further increase in nitrogen decreased in water use and recorded on par between $N_3$ to $N_4$ .

The interaction effect of irrigation and plant density was significant. At $I_1$, increase of plant density from $P_1$ to $P_3$ not effected the water use, whereas at $I_2$ and $I_3$ irrigation scheduling increase in plant density from $P_1$ to $P_3$ increase the water use. Significantly higher water use was recorded at $I_3$ x $P_3$ (492.70 mm) followed by $I_3$ X $P_2$ (486.40 mm), $I_2$ x $P_3$ (483.11 mm) and $I_2$ x $P_2$ (479.20 mm) interaction effects over others.

Increase in irrigation level from $I_1$ to $I_3$ accompanied with increase in nitrogen level from $N_1$ to $N_4$ significantly affected the water use. Significantly higher water use was recorded at $I_3$ x $N_4$ (487.69 mm) and was on par with $I_3$ x $N_3$ (486.51mm).

The increase in plant density from $P_1$ to $P_3$ at same level of nitrogen significantly increased the water use. Whereas, at same level of plant density the response to nitrogen

**Table 32. Water use (mm) of maize as influneced by irrigation scheduling, plant density and nitrogen levels**

| Year | 1998-99 | | | | 1999-2000 | | | | Pooled | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 411.46 | 414.36 | 412.74 | **412.85** | 390.12 | 394.07 | 394.21 | **392.80** | 400.79 | 404.22 | 403.48 | **402.83** |
| $I_1N_2$ | 411.77 | 415.40 | 418.06 | **415.08** | 395.67 | 400.53 | 403.17 | **399.79** | 403.72 | 407.97 | 410.62 | **407.43** |
| $I_1N_3$ | 392.16 | 388.88 | 384.85 | **388.63** | 375.34 | 371.18 | 368.36 | **371.63** | 383.75 | 380.03 | 376.61 | **380.13** |
| $I_1N_4$ | 391.53 | 388.52 | 383.84 | **387.96** | 374.12 | 367.75 | 365.70 | **369.19** | 382.83 | 378.14 | 374.77 | **378.58** |
| **Mean** | **401.73** | **401.79** | **399.87** | **401.13** | **383.81** | **383.38** | **382.86** | **383.35** | **392.77** | **392.59** | **391.37** | **392.24** |
| $I_2N_1$ | 461.31 | 470.76 | 473.62 | **468.56** | 468.97 | 472.10 | 474.84 | **471.97** | 465.14 | 471.43 | 474.23 | **470.27** |
| $I_2N_2$ | 467.11 | 479.29 | 479.71 | **475.37** | 474.76 | 480.26 | 486.41 | **480.48** | 470.94 | 479.78 | 483.06 | **477.92** |
| $I_2N_3$ | 466.70 | 483.06 | 485.44 | **478.40** | 475.19 | 483.46 | 488.78 | **482.48** | 470.95 | 483.26 | 487.11 | **480.44** |
| $I_2N_4$ | 466.73 | 483.31 | 485.79 | **478.61** | 475.19 | 483.74 | 490.29 | **483.07** | 470.96 | 483.53 | 488.04 | **480.84** |
| **Mean** | **465.46** | **479.11** | **481.14** | **475.24** | **473.53** | **479.89** | **485.08** | **479.50** | **469.50** | **479.50** | **483.11** | **477.37** |
| $I_3N_1$ | 464.72 | 476.63 | 481.25 | **474.20** | 476.92 | 485.54 | 493.17 | **485.21** | 470.82 | 481.09 | 487.21 | **479.71** |
| $I_3N_2$ | 469.18 | 482.99 | 488.22 | **480.13** | 481.05 | 489.59 | 496.97 | **489.20** | 475.12 | 486.29 | 492.60 | **484.67** |
| $I_3N_3$ | 471.04 | 484.06 | 491.46 | **482.19** | 481.96 | 492.21 | 498.30 | **490.82** | 476.50 | 488.14 | 494.88 | **486.51** |
| $I_3N_4$ | 471.14 | 487.97 | 493.68 | **484.26** | 482.60 | 492.17 | 498.56 | **491.11** | 476.87 | 490.07 | 496.12 | **487.69** |
| **Mean** | **469.02** | **482.91** | **488.65** | **480.20** | **480.63** | **489.88** | **496.75** | **489.09** | **474.83** | **486.40** | **492.70** | **484.64** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 445.83 | 453.92 | 455.87 | **451.87** | 445.34 | 450.57 | 454.07 | **449.99** | 445.58 | 452.24 | 454.97 | **450.93** |
| **N2** | 449.35 | 459.23 | 462.00 | **456.86** | 450.49 | 456.79 | 462.18 | **456.49** | 449.92 | 458.01 | 462.09 | **456.67** |
| **N3** | 443.30 | 452.00 | 453.92 | **449.74** | 444.16 | 448.95 | 451.81 | **448.31** | 443.73 | 450.48 | 452.87 | **449.02** |
| **N4** | 443.13 | 453.27 | 454.44 | **450.28** | 443.97 | 447.89 | 451.52 | **447.79** | 443.55 | 450.58 | 452.98 | **449.04** |
| **Mean** | **445.40** | **454.60** | **456.56** | **452.19** | **445.99** | **451.05** | **454.90** | **450.65** | **445.70** | **452.83** | **455.73** | **451.42** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | 1.25 | 4.93 | 2.00 | 4.71 | 0.87 | 2.83 |
| **Plant Density (P)** | 0.49 | 1.36 | 0.58 | 2.29 | 0.43 | 1.26 |
| **Nitrogen levels (N)** | 0.57 | 1.57 | 0.67 | 1.87 | 0.43 | 1.18 |
| **I X P** | 0.85 | 2.34 | 1.01 | 2.80 | 0.75 | 2.18 |
| **I X N** | 0.98 | 2.71 | 1.17 | 3.23 | 0.74 | 2.04 |
| **P X N** | 0.98 | 2.71 | 1.17 | 3.23 | 0.74 | 2.04 |
| **I X P X N** | 1.69 | 4.70 | 2.02 | 5.60 | 1.08 | 2.97 |

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants $ha^{-1}$; $P_2$ = 83333 Plants $ha^{-1}$; $P_3$ = 111111 Plants $ha^{-1}$ Nitrogen levels (N) : $N_1$ = 75 Kg $ha^{-1}$; $N_2$ = 150 Kg $ha^{-1}$; $N_3$ = 225 Kg $ha^{-1}$; $N_4$ = 300 Kg $ha^{-1}$

Table 33. Water use efficiency (kg ha$^{-1}$ mm$^{-1}$) of maize as influenced by irrigation scheduling, plant density and nitrogen levels

| Year | 1998-99 | | | | 1999-2000 | | | | Pooled | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** |
| **$I_1N_1$** | 14.59 | 13.85 | 13.43 | **13.96** | 16.39 | 15.58 | 15.12 | **15.70** | 15.49 | 14.71 | 14.28 | **14.83** |
| **$I_1N_2$** | 14.93 | 15.95 | 16.18 | **15.69** | 16.37 | 16.99 | 17.30 | **16.89** | 15.65 | 16.47 | 16.74 | **16.29** |
| **$I_1N_3$** | 15.17 | 15.64 | 16.03 | **15.61** | 16.20 | 16.45 | 17.64 | **16.76** | 15.68 | 16.04 | 16.83 | **16.19** |
| **$I_1N_4$** | 15.18 | 15.44 | 15.86 | **15.49** | 16.30 | 16.49 | 17.46 | **16.75** | 15.74 | 15.96 | 16.66 | **16.12** |
| **Mean** | **14.97** | **15.22** | **15.38** | **15.19** | **16.32** | **16.38** | **16.88** | **16.52** | **15.64** | **15.80** | **16.13** | **15.86** |
| **$I_2N_1$** | 14.21 | 12.77 | 11.63 | **12.87** | 15.27 | 13.41 | 12.32 | **13.67** | 14.74 | 13.09 | 11.97 | **13.27** |
| **$I_2N_2$** | 15.21 | 15.85 | 16.39 | **15.82** | 16.72 | 17.39 | 17.85 | **17.32** | 15.96 | 16.62 | 17.12 | **16.57** |
| **$I_2N_3$** | 15.31 | 16.85 | 17.76 | **16.64** | 16.82 | 18.22 | 18.72 | **17.92** | 16.07 | 17.54 | 18.24 | **17.28** |
| **$I_2N_4$** | 15.30 | 16.92 | 17.80 | **16.67** | 16.52 | 18.29 | 18.64 | **17.82** | 15.91 | 17.61 | 18.22 | **17.25** |
| **Mean** | **15.01** | **15.60** | **15.90** | **15.50** | **16.33** | **16.83** | **16.88** | **16.68** | **15.67** | **16.21** | **16.39** | **16.09** |
| **$I_3N_1$** | 14.04 | 12.31 | 10.99 | **12.45** | 15.09 | 12.51 | 11.47 | **13.02** | 14.56 | 12.41 | 11.23 | **12.74** |
| **$I_3N_2$** | 15.08 | 15.78 | 15.96 | **15.61** | 16.01 | 17.06 | 17.58 | **16.88** | 15.54 | 16.42 | 16.77 | **16.24** |
| **$I_3N_3$** | 15.08 | 17.03 | 17.39 | **16.50** | 16.36 | 18.03 | 18.54 | **17.65** | 15.72 | 17.53 | 17.96 | **17.07** |
| **$I_3N_4$** | 15.20 | 16.97 | 17.41 | **16.52** | 16.48 | 18.14 | 18.55 | **17.72** | 15.84 | 17.56 | 17.98 | **17.12** |
| **Mean** | **14.85** | **15.52** | **15.44** | **15.27** | **15.98** | **16.44** | **16.54** | **16.32** | **15.42** | **15.98** | **15.99** | **15.79** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 14.28 | 12.98 | 12.02 | **13.09** | 15.59 | 13.83 | 12.97 | **14.13** | 14.93 | 13.41 | 12.50 | **13.61** |
| **N2** | 15.07 | 15.86 | 16.18 | **15.70** | 16.37 | 17.15 | 17.58 | **17.03** | 15.72 | 16.50 | 16.88 | **16.37** |
| **N3** | 15.19 | 16.51 | 17.06 | **16.25** | 16.46 | 17.57 | 18.30 | **17.44** | 15.82 | 17.04 | 17.68 | **16.85** |
| **N4** | 15.22 | 16.44 | 17.02 | **16.23** | 16.43 | 17.64 | 18.22 | **17.43** | 15.83 | 17.04 | 17.62 | **16.83** |
| **Mean** | **14.94** | **15.45** | **15.57** | **15.32** | **16.21** | **16.55** | **16.77** | **16.51** | **15.58** | **16.00** | **16.17** | **15.91** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | 0.008 | 0.030 | 0.008 | 0.030 | 0.034 | 0.111 |
| **Plant Density (P)** | 0.032 | 0.089 | 0.031 | 0.086 | 0.027 | 0.079 |
| **Nitrogen levels (N)** | 0.037 | 0.103 | 0.036 | 0.099 | 0.024 | 0.067 |
| **I X P** | 0.056 | 0.154 | 0.054 | 0.148 | 0.047 | 0.138 |
| **I X N** | 0.064 | 0.178 | 0.062 | 0.171 | 0.042 | 0.116 |
| **P X N** | 0.064 | 0.178 | 0.062 | 0.171 | 0.042 | 0.116 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **I X P X N** | 0.111 | 0.308 | 0.107 | 0.296 | 0.073 | 0.202 |

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants $ha^{-1}$; $P_2$ = 83333 Plants $ha^{-1}$; $P_3$ = 111111 Plants $ha^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg $ha^{-1}$;$N_2$ = 150 Kg $ha^{-1}$; $N_3$ = 225 Kg $ha^{-1}$;$N_4$ = 300 Kg $ha^{-1}$

**Table 34. Nitrogen content of grain in per cent of maize at physiological maturity as influenced by irrigation scheduling, plant density and nitrogen levels**

| Year | 1998-99 | | | | 1999-2000 | | | | Pooled | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** |
| **$I_1N_1$** | 1.03 | 1.03 | 1.03 | **1.03** | 0.97 | 1.00 | 1.00 | **0.99** | 1.00 | 1.01 | 1.02 | **1.01** |
| **$I_1N_2$** | 1.61 | 1.54 | 1.51 | **1.55** | 1.61 | 1.55 | 1.47 | **1.54** | 1.61 | 1.55 | 1.49 | **1.55** |
| **$I_1N_3$** | 1.74 | 1.74 | 1.74 | **1.74** | 1.76 | 1.75 | 1.75 | **1.75** | 1.75 | 1.75 | 1.75 | **1.75** |
| **$I_1N_4$** | 1.74 | 1.74 | 1.74 | **1.74** | 1.76 | 1.75 | 1.75 | **1.75** | 1.75 | 1.75 | 1.75 | **1.75** |
| **Mean** | **1.53** | **1.51** | **1.50** | **1.51** | **1.53** | **1.51** | **1.49** | **1.51** | **1.53** | **1.51** | **1.50** | **1.51** |
| **$I_2N_1$** | 0.99 | 1.00 | 1.00 | **1.00** | 0.90 | 0.95 | 0.96 | **0.93** | 0.95 | 0.98 | 0.98 | **0.97** |
| **$I_2N_2$** | 1.50 | 1.44 | 1.40 | **1.45** | 1.42 | 1.34 | 1.31 | **1.36** | 1.46 | 1..39 | 1.36 | **1.41** |
| **$I_2N_3$** | 1.70 | 1.70 | 1.75 | **1.72** | 1.69 | 1.67 | 1.65 | **1.67** | 1.70 | 1.69 | 1.70 | **1.70** |
| **$I_2N_4$** | 1.70 | 1.70 | 1.70 | **1.70** | 1.70 | 1.69 | 1.69 | **1.70** | 1.70 | 1.70 | 1.70 | **1.70** |
| **Mean** | **1.48** | **1.46** | **1.46** | **1.47** | **1.43** | **1.41** | **1.40** | **1.41** | **1.45** | **1.45** | **1.43** | **1.45** |
| **$I_3N_1$** | 0.96 | 0.99 | 0.99 | **0.98** | 0.85 | 0.94 | 0.93 | **0.91** | 0.91 | 0.97 | 0.96 | **0.94** |
| **$I_3N_2$** | 1.47 | 1.42 | 1.35 | **1.42** | 1.39 | 1.33 | 1.25 | **1.32** | 1.43 | 1.38 | 1.30 | **1.37** |
| **$I_3N_3$** | 1.70 | 1.69 | 1.68 | **1.69** | 1.69 | 1.66 | 1.63 | **1.66** | 1.70 | 1.68 | 1.66 | **1.68** |
| **$I_3N_4$** | 1.70 | 1.70 | 1.70 | **1.70** | 1.69 | 1.69 | 1.67 | **1.68** | 1.70 | 1.70 | 1.69 | **1.70** |
| **Mean** | **1.46** | **1.45** | **1.43** | **1.45** | **1.41** | **1.41** | **1.37** | **1.39** | **1.43** | **1.43** | **1.40** | **1.42** |
| **NXP Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 1.00 | 1.01 | 1.01 | **1.00** | 0.91 | 0.96 | 0.96 | **0.94** | 0.95 | 0.98 | 0.99 | **0.97** |
| **N2** | 1.53 | 1.47 | 1.42 | **1.47** | 1.47 | 1.41 | 1.34 | **1.41** | 1.50 | 1.44 | 1.38 | **1.44** |
| **N3** | 1.71 | 1.71 | 1.72 | **1.72** | 1.71 | 1.70 | 1.68 | **1.69** | 1.72 | 1.70 | 1.70 | **1.71** |
| **N4** | 1.71 | 1.71 | 1.71 | **1.71** | 1.72 | 1.71 | 1.71 | **1.71** | 1.72 | 1.71 | 1.71 | **1.71** |
| **Mean** | **1.49** | **1.47** | **1.47** | **1.48** | **1.45** | **1.44** | **1.42** | **1.44** | **1.47** | **1.46** | **1.44** | **1.46** |

| | 1998-99 | | 1999-2000 | | Pooled | |
|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | 0.0026 | 0.0102 | 0.0018 | 0.0071 | 0.0016 | 0.0052 |
| **Plant Density (P)** | 0.0009 | 0.0025 | 0.0018 | 0.0071 | 0.0011 | 0.0032 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Nitrogen levels (N)** | 0.0010 | 0.0028 | 0.0021 | 0.0058 | 0.0012 | 0.0033 |
| **I X P** | 0.0015 | 0.0042 | 0.0032 | 0.0089 | 0.0019 | 0.0055 |
| **I X N** | 0.0018 | 0.0050 | 0.0037 | 0.0103 | 0.0020 | 0.0055 |
| **P X N** | 0.0018 | 0.0050 | 0.0037 | 0.0103 | 0.0020 | 0.0055 |
| **I X P X N** | 0.0031 | 0.0086 | 0.0064 | 0.0177 | 0.0035 | 0.0097 |

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants $ha^{-1}$; $P_2$ = 83333 Plants $ha^{-1}$; $P_3$ = 111111 Plants $ha^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg $ha^{-1}$;$N_2$ = 150 Kg $ha^{-1}$; $N_3$ = 225 Kg $ha^{-1}$;$N_4$ = 300 Kg $ha^{-1}$

**Table 35. Nitrogen uptake (kg $ha^{-1}$) of maize as influenced by irrigation scheduling, plant density and nitrogen levels**

| Year | 1998-99 | | | | 1999-2000 | | | | Pooled | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | $P_1$ | $P_2$ | $P_3$ | **Mean** | $P_1$ | $P_2$ | $P_3$ | **Mean** | $P_1$ | $P_2$ | $P_3$ | **Mean** |
| $I_1N_1$ | 85 | 89 | 93 | **89** | 83 | 87 | 92 | **87** | 84 | 88 | 93 | **88** |
| $I_1N_2$ | 133 | 147 | 156 | **145** | 135 | 146 | 156 | **146** | 134 | 147 | 156 | **146** |
| $I_1N_3$ | 151 | 167 | 177 | **165** | 155 | 168 | 186 | **170** | 153 | 168 | 182 | **167** |
| $I_1N_4$ | 151 | 165 | 175 | **164** | 154 | 168 | 183 | **168** | 153 | 167 | 179 | **166** |
| **Mean** | **130** | **142** | **150** | **141** | **132** | **142** | **154** | **143** | **131** | **142** | **152** | **142** |
| $I_2N_1$ | 88 | 94 | 98 | **93** | 87 | 93 | 97 | **92** | 88 | 94 | 98 | **93** |
| $I_2N_2$ | 128 | 157 | 168 | **151** | 139 | 157 | 168 | **155** | 134 | 157 | 168 | **153** |
| $I_2N_3$ | 170 | 204 | 218 | **197** | 184 | 208 | 221 | **204** | 177 | 206 | 220 | **201** |
| $I_2N_4$ | 170 | 205 | 224 | **200** | 184 | 220 | 241 | **215** | 177 | 213 | 233 | **207** |
| **Mean** | **139** | **165** | **177** | **160** | **149** | **170** | **182** | **167** | **144** | **167** | **179** | **163** |
| $I_3N_1$ | 85 | 91 | 96 | **91** | 84 | 90 | 94 | **89** | 85 | 91 | 95 | **90** |
| $I_3N_2$ | 132 | 157 | 166 | **152** | 134 | 156 | 164 | **151** | 133 | 157 | 165 | **152** |
| $I_3N_3$ | 170 | 201 | 216 | **196** | 182 | 204 | 218 | **201** | 176 | 203 | 217 | **199** |
| $I_3N_4$ | 171 | 208 | 229 | **203** | 185 | 222 | 245 | **217** | 178 | 215 | 237 | **210** |
| **Mean** | 140 | 164 | 177 | **160** | **146** | **168** | **180** | **165** | **143** | **166** | **179** | **163** |
| **NXP Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 86 | 91 | 96 | **91** | 85 | 90 | 94 | **90** | 85 | 91 | 95 | **90** |
| **N2** | 131 | 154 | 163 | **149** | 136 | 153 | 163 | **151** | 134 | 153 | 163 | **150** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **N3** | 164 | 191 | 204 | **186** | 174 | 193 | 208 | **192** | 169 | 192 | 206 | **189** |
| **N4** | 164 | 193 | 209 | **189** | 174 | 203 | 223 | **200** | 169 | 198 | 216 | **194** |
| **Mean** | **136** | **157** | **168** | **154** | **142** | **160** | **172** | **158** | **139** | **159** | **170** | **156** |

| | **1998-99** | | **1999-2000** | | **Pooled** | |
|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | 0.64 | 2.50 | 5.910 | 2.32 | 0.32 | 1.04 |
| **Plant Density (P)** | 0.73 | 2.01 | 0.730 | 2.865 | 0.35 | 1.14 |
| **Nitrogen levels (N)** | 0.84 | 2.32 | 0.843 | 2.336 | 0.43 | 1.39 |
| **I X P** | 1.26 | 3.48 | 1.265 | 3.506 | 0.61 | 1.97 |
| **I X N** | 1.45 | 4.02 | 1.460 | 4.046 | 0.74 | 3.39 |
| **P X N** | 1.45 | 4.02 | 1.460 | 4.046 | 0.74 | 3.39 |
| **I X P X N** | 2.51 | 6.97 | 2.530 | 7.013 | 1.28 | 4.16 |

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants $ha^{-1}$; $P_2$ = 83333 Plants $ha^{-1}$; $P_3$ = 111111 Plants $ha^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg $ha^{-1}$;$N_2$ = 150 Kg $ha^{-1}$; $N_3$ = 225 Kg $ha^{-1}$;$N_4$ = 300 Kg $ha^{-1}$

was significant upto $N_2$, however significantly higher water use of 462.09 mm was recorded at $N_2 \times P_3$ interaction effect over others.

The water use of maize differed significantly due to interaction effect of irrigation scheduling, plant density and nitrogen level. With the increase in irrigation level from $I_1$ to $I_3$,, accompanied by increase of plant density from $P_1$ to $P_3$ and nitrogen level from $N_1$ to $N_3$, significantly differed in water use. Irrigation scheduling at $I_1$ (0.6 IW/CPE ratio) with different levels of plant densities and increase in nitrogen levels from $N_1$ and $N_2$ significantly increased the water use and recorded higher at $I_1xP_2XN_3$ (410.62 mm). And, at $I_2$ and $I_3$ irrigation scheduling with $P_1$, $P_2$ and $P_3$, water use increased from $N_l$ to $N_2$, $N_l$ to $N_4$ and $N_l$ to $N_4$ respectively. However, higher water use was recorded in $I_3$ x $P_3$ X $N_4$ (496.12 mm) which was statistically on par with $I_3$ x $P_3$ X $N_3$ (494.88 mm) and significantly higher over others.

4.2.5.2 Water use efficiency (kg ha$^{-l}$ mm$^{-l}$) (cf. Table 33)

The water use efficiency significantly varied due to irrigation scheduling, plant density and nitrogen levels during both the years.

Over the two years, water use efficiency significantly increased with increase in irrigation level from $I_1$ to $I_2$. Significantly higher water use efficiency of 16.09 kg ha$^{-l}$ mm$^{-l}$ was recorded at 0.9 IW / CPE ratio irrigation scheduling ($I_2$).

The increase in plant density from $P_1$ to $P_3$ significantly increased the water use efficiency by recording higher water use efficiency of 16.17 kg ha$^{-l}$ mm$^{-l}$ at $P_3$ plant density.

Increase in nitrogen level from $N_1$ to $N_3$ significantly increased the WUE and recorded 16.85 kg ha$^{-l}$ mm$^{-l}$ at $N_3$, which was statistically on par with $N_4$ ( 16.83 kg ha$^{-l}$ mm$^{-l}$ ).

The interaction effect of irrigation scheduling and plant density was significant. Increase in irrigation scheduling from $I_1$ to $I_2$ with increase in plant density from $P_1$ to $P_3$ significantly increased the water use efficiency. Significantly higher water use efficiency of 16.39 kg ha$^{-l}$ mm$^{-l}$ was obtained at $I_2$ x $P_3$ treatment combination over others.

Irrigation scheduling and nitrogen level interaction effect differed significantly. The higher water use efficiency of 17.28 kg ha$^{-l}$ mm$^{-l}$ was recorded at $I_2$ (0.9 IW /CPE ratio) coupled with $N_3$ (225 kg ha$^{-1}$) and was on par with $I_2$ x $N_4$ (17.25 kg ha$^{-l}$ mm$^{-l}$).

The interaction effect of plant density with nitrogen level was significant. Increase in plant density from $P_1$ to $P_3$ with increase in nitrogen level from $N_1$ to $N_4$ showed differential response on water use efficiency. The higher WUE of 17.68 kg ha$^{-l}$ mm$^{-l}$ was recorded for plant density of $P_3$ with nitrogen level at $N_3$, which was statistically on par with $P_3$ x $N_4$ (17.62 kg ha$^{-l}$ mm$^{-l}$) and were significantly higher than other interaction effects.

The interaction effect of irrigation scheduling, plant density and nitrogen level was significant. The increase in irrigation scheduling from $I_1$ to $I_2$ coupled with increase in plant density from $P_1$ to $P_3$ and nitrogen level from $N_1$ to $N_3$ increased WUE. Significantly higher water use efficiency of 18.24 kg ha$^{-l}$ mm$^{-l}$ was obtained at $I_2$ (0.9 IW/CPE ratio) coupled with plant density of $P_3$ (111111 plants ha$^{-l}$) and nitrogen level of $N_3$ (225 kg ha$^{-l}$), and was on par with $I_2$ x $P_3$ X $N_4$ (18.22 kg ha$^{-l}$ mm$^{-l}$).

4.2.6 Nitrogen content and uptake at physiological maturity

4.2.6.1 Nitrogen content of grain in per cent (cf. Table 34)

The percent nitrogen content in grain varied significantly due to irrigation scheduling, plant density and nitrogen level during both the years.

Increase in irrigation level from $I_1$ to $I_3$ significantly decreased the percent nitrogen in grain. Significantly higher nitrogen content in grain (1.51 per cent) was recorded in irrigation scheduling at $I_1$ (0.6 IW /CPE ratio) over other levels.

The per cent nitrogen content in grain significantly decreased due to increase in plant density. Significantly higher nitrogen content in grain (1.47 per cent) was registered in plant density at $P_1$ over $P_2$ (1.46 per cent) and $P_3$ (1.44 per cent).

The increase in nitrogen level from $N_1$ to $N_3$ significantly increased the nitrogen content in grain. The $N_3$ and $N_4$ recorded statistically on par nitrogen content in grain (1.71 per cent at each level).

The interaction effect of irrigation scheduling and plant density was significant. The increase in irrigation level from $I_1$ to $I_3$ with increase in plant density from $P_1$ to $P_3$ significantly reduced the nitrogen per cent in grain. Maximum and minimum nitrogen per cent in grain was recorded in $I_1XP_1$ (1.53 per cent) and $I_3$ x $P_3$ (1.40 per cent) interactions respectively.

Interaction effect of irrigation scheduling and nitrogen levels with respect to per cent nitrogen in grain differed significantly. Increase in irrigation level from $I_1$ to $I_3$ at same level of nitrogen significantly reduced the per cent nitrogen in grain, while increase in nitrogen from $N_1$ to $N_3$ at same level of irrigation significantly increased the percent nitrogen in grain. However, higher and lower nitrogen content in grain recorded with $I_1$ x $N_3$ (1.75 per cent) and $I_3$ x $N_l$ (0.94 per cent) treatment combinations respectively.

The nitrogen content in grain due to interaction of plant density and nitrogen level was significant. Increase in plant density at same level of nitrogen decreased the percent nitrogen content. Increase of nitrogen from $N_1$ to $N_3$ at same level of plant density significantly increased the percent nitrogen in grain. The higher nitrogen content of grain 1.72 per cent was recorded at $P_1$ x $N_3$ over other interactions.

The interaction effect due to irrigation scheduling, plant density and nitrogen level showed significant difference in per cent nitrogen in grain. The per cent nitrogen content in grain recorded at $I_1$ x $P_l$ x $N_3$, $I_1$ x $P_l$ x $N_4$, $I_1$ x $P_2$ x $N_3$, $I_1$ x $P_2$ x $N_4$, $I_1$ x $P_3$ x $N_3$ and $I_1$ x $P_3$ x $N_4$ (1.75 per cent at each combination) was on par and were significantly higher than other interactions.

**4.2.6.2 Crop nitrogen uptake (kg ha$^{-l}$) (cf. Table 35)**

The crop nitrogen uptake was significant due to irrigation scheduling, plant density and nitrogen level during both the years.

Increase in irrigation level from $I_1$ to $1_2$ significantly increased the crop nitrogen uptake from 142 to 163 kg ha$^{-1}$ respectively.

Crop nitrogen uptake significantly increased from 139 to 170 kg ha$^{-1}$ with increase in plant density from $P_1$ to $P_3$ respectively.

Increase in nitrogen level from $N_l$ to $N_4$ significantly increased the crop nitrogen uptake and recorded significantly higher at $N_4$ (194 kg ha$^{-1}$) over other nitrogen levels.

Increase in irrigation scheduling from $I_1$ to $I_2$ coupled with increase in plant density from $P_1$ to $P_3$ significantly increased the nitrogen uptake. Significantly higher nitrogen uptake (179 kg ha$^{-1}$) was recorded at $I_2xP_3$ and $I_3xP_3$ interactions over other treatment combinations.

The interaction between irrigation scheduling and nitrogen was significant. Increase in irrigation level from $I_1$ to $I_2$ with increase in nitrogen level from $N_1$ to $N_4$ significantly increased the nitrogen uptake. Significantly higher nitrogen uptake of 210 kg ha$^{-l}$ was recorded for $I_3$ x $N_4$ interactions and was on par with $I_2$ x $N_4$ (207 kg ha$^{-l}$).

The plant density and nitrogen interaction effect was significant. Increase in plant density from $P_1$ to $P_3$ with increase in nitrogen level from $N_l$ to $N_4$ significantly increased the crop nitrogen uptake. Significantly higher nitrogen uptake of 216 kg ha$^{-l}$ was recorded at $P_3$ x $N_4$ interaction as compared to other plant density and nitrogen interactions.

The interaction effect due to irrigation scheduling, plant density and nitrogen level was also significant. Increase in irrigation level from $I_1$ to $I_2$ coupled with increase in plant density from $P_1$ to $P_3$ and nitrogen level from $N_1$ to $N_4$ significantly increased the crop nitrogen uptake. Significantly higher crop nitrogen uptake of 237 kg ha$^{-l}$ was recorded at $I_3$ x $P_3$ X $N_4$ interaction as compared to others, except $I_2$ x $P_3$ X $N_4$ (233 kg ha$^{-1}$)

## 4.2.7 Correlation studies (cf. Table 36)

Highly significant correlation was observed between grain yield and LAI at 60 DAS (r=0.79), LAI at physiological maturity (r=0.96), leaf dry matter at 90 DAS ( r=91), 120 DAS (r=0.96) and physiological maturity (r=0.91), stem dry matter at physiological maturity (r=0.78), cob dry matter at 90 DAS (r=0.98), 120 DAS (r=0.97) and at physiological maturity (r=0.96), total dry matter at 90 DAS (r=0.94), at 120 DAS (r=0.98), at physiological maturity ( r=0.95), harvest index ( r=0.78), grain weight(r=0.78), grains ear$^{-1}$ (r=0.97), grain number m$^{-2}$ (r=0.99), nitrogen content (r=0.86) and N- uptake (r=0.89)

**Table 36. Correlation co-efficient between various characters and grain yield as influenced by irrigation scheduling, plant density and nitrogen levels**

| Sl.No. | Characters | Correlation co-efficient |
|---|---|---|
| 1 | Plant height at 30 DAS | 0.52 |
| 2 | Plant height at 60 DAS | 0.69* |
| 3 | Plant height at 90 DAS & physiological maturity | 0.23 |
| 4 | LAI at 30 DAS | -0.41 |
| 5 | LAI at 60 DAS | 0.79* |
| 6 | LAI at 90 DAS | 0.18 |
| 7 | LAI at 120 DAS | 0.18 |
| 8 | LAI at physiological maturity | 0.96** |
| 9 | Leaf dry matter at 30 DAS | -0.39 |
| 10 | Leaf dry matter at 60 DAS | 0.76* |
| 11 | Leaf dry matter at 90 DAS | 0.91** |
| 12 | Leaf dry matter at 120 DAS | 0.96** |
| 13 | Leaf dry matter at physiological maturity | 0.91** |
| 14 | Stem dry matter at 30 DAS | -0.37 |
| 15 | Stem dry matter at 60 DAS | 0.451 |
| 16 | Stem dry matter at 90 DAS | 0.65* |
| 17 | Stem dry matter at 120 DAS | 0.75* |
| 18 | Stem dry matter at physiological maturity | 0.78* |
| 19 | Cob dry matter at 90 DAS | 0.98** |
| 20 | Cob dry matter at 120 DAS | 0.98** |
| 21 | Cob dry matter at physiological maturity | 0.96** |
| 22 | Total dry matter at 30 DAS | -0.39 |
| 23 | Total dry matter at 60 DAS | 0.58 |
| 24 | Total dry matter at 90 DAS | 0.94** |
| 25 | Total dry matter at 120 DAS | 0.98** |
| 26 | Total dry matter at physiological maturity | 0.95** |
| 28 | Harvest Index | 0.78* |
| 29 | Grain weight | 0.73* |
| 30 | Grains ear$^{-1}$ | 0.97** |
| 31 | Grain number m$^{-2}$ | 0.99** |
| 32 | Water use | 0.62 |
| 33 | WUE | 0.99** |
| 34 | Nitrogen content | 0.86** |
| 35 | N uptake | 0.89** |

**- Significant at 0.01 levels of probability

* - Significant at 0.05 levels of probability

TDM: Total dry matter, DAS: Days after sowing

## 4.2.8 Economics (cf. Table 37 and Appendix 22)

The economic indicators such as cost of production (Rs. $ha^{-l}$), gross return (Rs. $ha^{-l}$), net return (Rs. $ha^{-l}$) and benefit cost ratio (Rs. per Rs. investment) were worked out, and these indicators were greatly influenced by irrigation scheduling, plant density and nitrogen levels.

Increase in irrigation scheduling, plant density and nitrogen level increased the cost of production. The higher cost of production was recorded for irrigation scheduling at $I_3$ (Rs. 15306 $ha^{-1}$), plant density at $P_3$ (Rs. 15452 $ha^{-1}$) and nitrogen level at $N_4$(Rs. 15874 $ha^{-1}$).

Gross return increased with increase in irrigation scheduling from $I_l$ (Rs. 33613 $ha^{-1}$) to $I_2$(Rs. 41498 $ha^{-1}$), plant density from $P_1$(Rs. 36908 $ha^{-1}$) to $P_3$ (Rs. 40306 $ha^{-1}$) and nitrogen level from $N_1$ (Rs. 33103 $ha^{-1}$) to $N_3$ (Rs. 40955 $ha^{-1}$). The higher was recorded with irrigation scheduling at $1_2$ (Rs.41498 $ha^{-1}$) plant density at $P_3$ (Rs. 40306 $ha^{-1}$) and nitrogen level at $N_3$ (Rs.40955 $ha^{-1}$).

Net return increased with increase in irrigation scheduling from $I_1$ (Rs. 19488 $ha^{-1}$) to $I_2$ (Rs. 26472 $ha^{-1}$), plant density from $P_1$ (Rs. 22839 $ha^{-1}$) to $P_3$ (Rs. 24854 $ha^{-1}$) and nitrogen level from $N_1$ (Rs. 19541 $ha^{-1}$), to $N_2$ (Rs. 25736 $ha^{-1}$). The higher net return obtained with irrigation scheduling at $I_2$ (Rs.26472 $ha^{-l}$), plant density at $P_3$ (Rs. 24854 $ha^{-l}$) and nitrogen level at $N_2$ (Rs.25736 $ha^{-l}$).

The B:C ratio increased with increase in irrigation level from $I_1$ (2.39) to $I_2$(2.75), plant density from $P_1$(2.62) to $P_2$ (2.62) and nitrogen level from $N_l$ (2.45)to $N_2$(2.76). The higher ratio was recorded with irrigation scheduling at $I_2$ (2.75) plant density at $P_2$ (2.62) and nitrogen level at $N_2$ (2.76). The interaction between irrigation scheduling, plant density and nitrogen levels shown difference in cost of production, gross return, net return and B.C ratio. Higher cost of production (Rs 17257 $ha^{-1}$), gross return (Rs. 48583 $ha^{-1}$) noticed in $I_3P_3N_4$ treatment combination over others. However, $I_2P_3N_3$ treatment combination recorded higher net return (Rs 31959 $ha^{-1}$) and B:C ratio (2.96)

# 4.3 DSSAT v 3.5 CERES MAIZE MODEL: SIMULATION STUDIES

## 4.3.1 Genetic coefficients (cf. Table 38)

The genetic coefficients were calculated by using GENCALC- programme of DSSAT v 3.5. The growing degree days (base $8^0$C) from emergence to the end of juvenile phase ($P_1$) was 280 degree days for Deccan-103, DMH-1 and Prabha; 275 and 120 degree days for DMH-2 and Renuka, respectively. The degree days from (base $8^0$c) silking to maturity (P5) was 940 for Deccan-103 and DMH-1, 1030, 945 and 750 degree days for DMH-2, Prabha and Renuka respectively. And, degree days for leaf appearance (PHINT) were set to 48 degree days. The potential number of grains per plant (G2) was 730 for DMH-1 and DMH-2, 720, 690 and 719 for Prabha, Deccan-103 and Renuka respectively. Further, the potential grain growth rate during the linear grain filling stage (G3) was adjusted to 7 mg $day^{-l}$ for DMH-1 and DMH-2, 6.5, 5.8 and 5.7 mg $day^{-l}$ for Deccan-103, Prabha and Renuka respectively. The P2 was set to 0.52 for all the varieties, except Renuka for which P2 was set to 0.30.

## 4.3.2 Simulation of planting dates and varieties

The field experimentation and DSSAT v 3.5 CERES-maize model simulation results of the effect of planting dates on growth and yield of maize varieties were statistically compared and presented as detailed below.

### 4.3.2.1 Measured v/s simulated number of leaves $plant^{-l}$ (cf. Table 39)

The CERES-maize model simulated the number of leaves at different growth stages. As the number of leaves at anthesis remains same as that of physiological maturity, simulated number of leaves were compared only for two stages such as 30 DAS and at physiological maturity. The comparison at 30 DAS showed that for 1998-99 and 1999- 2000 the RMSE (root mean square error) was 1.12 and 1.05, and CRM (coefficient of residual mass) was -12.08 and -11.65 respectively. At physiological maturity between 1998-99 and1999- 2000 the RMSE was 2.91 and 2.90, and CRM was -16.34 and -16.40 respectively. As the RMSE was used to estimate the variation expressed in the same unit as that of experimental data, the

**Table 37. Economics of maize as influenced by irrigation scheduling, plant density and nitrogen levels(pooled data of two years)**

| Treatments | Cost of production @ Rs. ha$^{-1}$ | | | | Gross return @ Rs. ha$^{-1}$ | | | | Net return @ Rs. ha$^{-1}$ | | | | Benefit cost ratio | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P1 | P2 | P3 | Mean | P1 | P2 | P3 | Mean | P1 | P2 | P3 | Mean | P1 | P2 | P3 | Mean |
| $I_1N_1$ | 12655 | 13288 | 13676 | **13206** | 33051 | 32269 | 31603 | **32308** | 20396 | 18981 | 17927 | **19101** | 2.61 | 2.43 | 2.31 | **2.45** |
| $I_1N_2$ | 13205 | 14104 | 14628 | **13979** | 33648 | 36316 | 37472 | **35812** | 20444 | 22212 | 22844 | **21833** | 2.55 | 2.57 | 2.56 | **2.56** |
| $I_1N_3$ | 13640 | 14409 | 14968 | **14339** | 32144 | 33116 | 34642 | **33301** | 18504 | 18707 | 19674 | **18962** | 2.36 | 2.30 | 2.31 | **2.32** |
| $I_1N_4$ | 14297 | 15038 | 15583 | **14973** | 32181 | 32784 | 34126 | **33030** | 17884 | 17745 | 18542 | **18057** | 2.25 | 2.18 | 2.19 | **2.21** |
| Mean | **13449** | **14210** | **14714** | **14124** | **32756** | **33621** | **34461** | **33613** | **19307** | **19411** | **19747** | **19488** | **2.44** | **2.37** | **2.34** | **2.39** |
| $I_2N_1$ | 13218 | 13682 | 13947 | **13616** | 36342 | 33655 | 31544 | **33847** | 23124 | 19973 | 17598 | **20231** | 2.75 | 2.46 | 2.26 | **2.49** |
| $I_2N_2$ | 13988 | 14907 | 15489 | **14795** | 39943 | 43123 | 45069 | **42712** | 25955 | 28216 | 29581 | **27917** | 2.86 | 2.89 | 2.91 | **2.89** |
| $I_2N_3$ | 14562 | 15662 | 16339 | **15521** | 40191 | 45714 | 48297 | **44734** | 25629 | 30053 | 31959 | **29213** | 2.76 | 2.92 | 2.96 | **2.88** |
| $I_2N_4$ | 15186 | 16332 | 16996 | **16171** | 39822 | 45981 | 48293 | **44699** | 24636 | 29649 | 31297 | **28527** | 2.62 | 2.82 | 2.84 | **2.76** |
| Mean | **14239** | **15145** | **15693** | **15026** | **39075** | **42118** | **43301** | **41498** | **24836** | **26973** | **27608** | **26472** | **2.75** | **2.77** | **2.74** | **2.75** |
| $I_3N_1$ | 13524 | 13901 | 14165 | **13863** | 36323 | 32628 | 30511 | **33154** | 22798 | 18727 | 16347 | **19291** | 2.69 | 2.35 | 2.15 | **2.40** |
| $I_3N_2$ | 14235 | 15211 | 15786 | **15077** | 39267 | 43228 | 45109 | **42534** | 25032 | 28016 | 29322 | **27457** | 2.76 | 2.84 | 2.86 | **2.82** |
| $I_3N_3$ | 14832 | 15996 | 16591 | **15806** | 39829 | 46235 | 48427 | **44830** | 24997 | 30239 | 31836 | **29024** | 2.69 | 2.89 | 2.92 | **2.83** |
| $I_3N_4$ | 15511 | 16668 | 17257 | **16479** | 40156 | 46367 | 48583 | **45035** | 24645 | 29699 | 31326 | **28556** | 2.59 | 2.78 | 2.82 | **2.73** |
| Mean | **14525** | **15444** | **15950** | **15306** | **38894** | **42115** | **43157** | **41388** | **24368** | **26670** | **27208** | **26082** | **2.68** | **2.72** | **2.69** | **2.69** |
| NXP Interaction | P1 | P2 | P3 | **Mean** | P1 | P2 | P3 | **Mean** | P1 | P2 | P3 | **Mean** | P1 | P2 | P3 | **Mean** |
| N1 | 13133 | 13624 | 13929 | **13562** | 35239 | 32850 | 31220 | **33103** | 22106 | 19227 | 17290 | **19541** | 2.68 | 2.41 | 2.24 | **2.45** |
| N2 | 13809 | 14741 | 15301 | **14617** | 37619 | 40889 | 42550 | **40353** | 23810 | 26148 | 27249 | **25736** | 2.72 | 2.77 | 2.78 | **2.76** |
| N3 | 14345 | 15355 | 15966 | **15222** | 37388 | 41689 | 43789 | **40955** | 23043 | 26333 | 27823 | **25733** | 2.60 | 2.70 | 2.73 | **2.68** |
| N4 | 14998 | 16013 | 16612 | **15874** | 37386 | 41711 | 43667 | **40921** | 22388 | 25698 | 27055 | **25047** | 2.49 | 2.59 | 2.62 | **2.57** |
| Mean | **14071** | **14933** | **15452** | **14819** | **36908** | **39285** | **40306** | **38833** | **22837** | **24352** | **24854** | **24014** | **2.62** | **2.62** | **2.59** | **2.61** |

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$;$N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$;$N_4$ = 300 Kg ha$^{-1}$

## Table 38. Genetic coefficients of maize varieties

| Varieties | $P_1$ | $P_2$ | $P_5$ | $G_2$ | $G_3$ | PHINT |
|---|---|---|---|---|---|---|
| Deccan – 103 | 280 | 0.52 | 940 | 690 | 6.5 | 48 |
| DMH-1 | 280 | 0.52 | 940 | 730 | 7.0 | 48 |
| DMH-2 | 275 | 0.52 | 1030 | 730 | 7.0 | 48 |
| Prabha (G-57) | 280 | 0.52 | 945 | 720 | 5.8 | 48 |
| Renuka (G-25) | 120 | 0.30 | 750 | 719 | 5.7 | 48 |

**P-1:** Thermal time from seedling emergence to the end of the juvenile phase (expressed in growing degree days above a base temperature $8^0$ C) during which plant is not responsive to change in photoperiod.

**P-2:** Extent to which development (expressed as above) is delayed for each hour increase in photoperiod at which development proceeds at maximum rate (which is considered be 12.5 hours).

**P-5:** Thermal time from silking to physiological maturity (expressed in degree days above a base temperature of $8^0$ C).

**G-2:** Maximum possible number of kernels plant$^{-1}$.

**G-3:** Kernel filling rate during the linear grain filling stage under optimum condition (mg day$^{-1}$).

**PHINT:** Phylochron interval, the interval in thermal time (degree days) between successive leaf tip appearances.

variation between measured and simulated values in number of leaves at 30 DAS and at physiological maturity was 1.05 to 1.12, and 2.90 to 2.91 leaves respectively. The simulated values were little higher as compared to field measured values. The CRM values which vary from -11.65 to -12.08 at 30 DAS and -16.34 to -16.40 at physiological maturity indicated that the CERES-maize model overestimated the number of leaves to the extent of 11.65 to 12.08 per cent, and 16.34 to 16.40 per cent at 30 DAS and physiological maturity respectively.

#### 4.3.2.2 Measured v/s simulated leaf area index (cf. Table 40)

Leaf area index measured from field experimentation was compared with CERES-maize simulated values. The RMSE and CRM values for LAI between simulated and measured for 1998-99 and 1999-2000 seasons at 30 DAS were 0.04 and -5.35 and 0.05 and -8.44 respectively. The RMSE values were between 0.04 to 0.05 which indicated that the variation between measured and simulated were smaller. Further, the CRM values were negative between -5.35 and -8.44 indicated that the CERES-maize model. overpredicted the LAI between 5.35 and 8.44 per cent, during 1998-99 and 1999-2000 seasons respectively.

At anthesis, the smaller RMSE values of 0.12 during both the years and CRM values of -3.53 and -3.48 were registered for 1998-99 and 1999-2000 seasons respectively. As the RMSE values was 0.12 during both the year, the variation was smaller. Similarly, the CRM values were between -3.53 and -3.48 the tendency of the model prediction was towards over estimation to the extent of 3.53 to 3.48 per cent during 1998- 99 and 1999-2000 seasons respectively.

During physiological maturity, the RMSE and CRM values were 0.04 and 0.08, and -2.64 and -1.41 for 1998-99 and 1999-2000 seasons respectively. The variation was between 0.04 and 0.08. Further, the CRM values were -2.64 for 1998-99, and -1.41 for 1999-2000. This indicated that CERES-maize model overestimated to the extent of 2.64 per cent during 1998-99, 1.41 per cent during 1999-2000.

#### 4.3.2.3 Phenological stages (cf. Table 41)

#### 4.3.2.3.1 Measured v / s simulated days to 50 percent flowering

During 1998-99 the RMSE and CRM values for days to 50 per cent flowering were 0.95 and 1.20. It indicated that model prediction was very closer to experimental data. The CERES-maize model underestimated days to 50% flowering to the extent of 1.20 per cent.

**Table 39. Measured and simulated number of leaves of maize varieties at different growth stages as influenced by planting dates .**

| Treatments | 30DAS | | | | **Physiological maturity** | | | |
|---|---|---|---|---|---|---|---|---|
| | **1998-99** | | **1999-2000** | | **1998-99** | | **1999-2000** | |
| | **M** | **S** | **M** | **S** | **M** | **S** | **M** | **S** |
| $D_1V_1$ | 9.80 | 11.00 | 9.70 | 11.00 | 18.80 | 22.00 | 18.67 | 22.00 |
| $D_1V_2$ | 9.80 | 11.00 | 9.70 | 11.00 | 18.80 | 22.00 | 18.67 | 22.00 |
| $D_1V_3$ | 9.80 | 11.00 | 9.30 | 11.00 | 18.70 | 21.00 | 18.83 | 21.00 |
| $D_1V_4$ | 9.80 | 11.00 | 9.70 | 11.00 | 18.80 | 22.00 | 18.67 | 22.00 |
| $D_1V_5$ | 10.00 | 11.00 | 9.80 | 11.00 | 13.80 | 16.00 | 13.23 | 15.00 |
| $D_2V_1$ | 8.90 | 10.00 | 8.70 | 9.50 | 17.33 | 21.00 | 17.33 | 21.00 |
| $D_2V_2$ | 8.90 | 10.00 | 8.70 | 9.50 | 17.37 | 21.00 | 17.33 | 21.00 |
| $D_2V_3$ | 8.90 | 10.00 | 8.70 | 9.50 | 17.33 | 21.00 | 17.33 | 21.00 |
| $D_2V_4$ | 8.90 | 10.00 | 8.70 | 9.60 | 17.37 | 21.00 | 17.38 | 21.00 |
| $D_2V_5$ | 9.00 | 10.00 | 9.00 | 10.00 | 13.23 | 15.00 | 13.38 | 15.00 |
| $D_3V_1$ | 8.80 | 9.60 | 8.20 | 9.00 | 17.83 | 21.00 | 17.93 | 21.00 |
| $D_3V_2$ | 8.80 | 9.60 | 8.20 | 9.00 | 17.83 | 21.00 | 17.93 | 21.00 |
| $D_3V_3$ | 8.80 | 9.60 | 8.20 | 9.00 | 17.83 | 21.00 | 17.93 | 21.00 |
| $D_3V_4$ | 8.80 | 9.60 | 8.20 | 9.00 | 17.83 | 21.00 | 17.93 | 21.00 |
| $D_3V_5$ | 9.00 | 10.00 | 9.00 | 9.50 | 13.80 | 14.00 | 13.60 | 15.00 |
| $D_4V_1$ | 8.20 | 9.50 | 7.90 | 9.00 | 18.13 | 21.00 | 18.37 | 21.00 |
| $D_4V_2$ | 8.20 | 9.50 | 7.90 | 9.00 | 18.23 | 21.00 | 18.37 | 21.00 |
| $D_4V_3$ | 8.20 | 9.50 | 7.90 | 9.00 | 18.20 | 20.00 | 18.33 | 21.00 |
| $D_4V_4$ | 8.20 | 9.50 | 7.90 | 9.00 | 18.23 | 21.00 | 18.33 | 21.00 |
| $D_4V_5$ | 8.80 | 10.00 | 8.90 | 10.00 | 12.65 | 15.00 | 12.37 | 14.00 |
| **Mean** | 8.98 | 10.07 | 8.71 | 9.73 | 17.11 | 19.90 | 17.09 | 19.90 |
| **RMSE** | 1.12 | | 1.05 | | 2.91 | | 2.90 | |
| **CRM** | -12.08 | | -11.65 | | -16.34 | | -16.40 | |

DAS : Days after sowing
M : Measured; S : Simulated
RMSE : Root mean square error; CRM : Coefficient of residual mass
Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH -1 ; $V_3$ = DMH – 2
$V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).
Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight
$D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight

In 1999-2000 season, the RMSE and CRM values were 0.78 and 0.91. It revealed that the CERES maize model was very closer to the measured data. The CERES-maize model underestimated the days to 50 per cent flowering to the extent of 0.91 per cent.

**4.3.2.3.2 Measured v/s simulated days to physiological maturity**

The RMSE and CRM values for days to physiological maturity were 0.84 and 0.16, and 0.74 and 0.36 for 1998-99 and 1999-2000 season respectively. As the RMSE values were between 0.74 and 0.84 during both the seasons, the model predicted values were very nearer to field experimentation values. The CRM values were between 0.16 and 0.36. This clearly explained that the CERES-maize model underestimated the days to physiological maturity to the extent of 0.16 and 0.36 per cent during 1998-99 and 1999-2000 cropping periods respectively.

**Table 40. Measured and simulated LAI of maize varieties at different growth stages as influenced by planting dates**

| Treatments | 30 DAS | | | | Anthesis | | | | Physiological maturity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-99 | | 1999-2000 | | 1998-99 | | 1999-2000 | | 1998-99 | | 1999-2000 | |
| | M | S | M | S | M | S | M | S | M | S | M | S |
| $D_1V_1$ | 0.77 | 0.81 | 0.76 | 0.80 | 3.58 | 3.71 | 3.55 | 3.68 | 1.38 | 1.44 | 1.41 | 1.46 |
| $D_1V_2$ | 0.77 | 0.81 | 0.76 | 0.80 | 3.58 | 3.71 | 3.55 | 3.68 | 1.38 | 1.44 | 1.41 | 1.46 |
| $D_1V_3$ | 0.78 | 0.82 | 0.76 | 0.80 | 3.58 | 3.47 | 3.55 | 3.47 | 1.38 | 1.40 | 1.40 | 1.39 |
| $D_1V_4$ | 0.77 | 0.81 | 0.76 | 0.80 | 3.58 | 3.71 | 3.55 | 3.68 | 1.39 | 1.47 | 1.43 | 1.49 |
| $D_1V_5$ | 0.86 | 0.85 | 0.79 | 0.83 | 1.63 | 1.69 | 1.47 | 1.53 | 0.67 | 0.69 | 0.60 | 0.62 |
| $D_2V_1$ | 0.72 | 0.76 | 0.69 | 0.73 | 3.19 | 3.32 | 3.42 | 3.55 | 1.31 | 1.36 | 1.39 | 1.44 |
| $D_2V_2$ | 0.72 | 0.76 | 0.69 | 0.73 | 3.19 | 3.32 | 3.42 | 3.55 | 1.31 | 1.36 | 1.39 | 1.44 |
| $D_2V_3$ | 0.72 | 0.76 | 0.70 | 0.73 | 3.19 | 3.32 | 3.42 | 3.55 | 1.31 | 1.29 | 1.39 | 1.42 |
| $D_2V_4$ | 0.72 | 0.76 | 0.69 | 0.73 | 3.19 | 3.32 | 3.42 | 3.55 | 1.33 | 1.38 | 1.41 | 1.46 |
| $D_2V_5$ | 0.76 | 0.8 | 0.75 | 0.80 | 1.47 | 1.53 | 1.46 | 1.52 | 0.58 | 0.60 | 0.57 | 0.59 |
| $D_3V_1$ | 0.53 | 0.56 | 0.46 | 0.50 | 3.40 | 3.53 | 3.45 | 3.58 | 1.42 | 1.48 | 1.37 | 1.42 |
| $D_3V_2$ | 0.53 | 0.56 | 0.46 | 0.50 | 3.40 | 3.53 | 3.45 | 3.58 | 1.42 | 1.48 | 1.37 | 1.42 |
| $D_3V_3$ | 0.53 | 0.56 | 0.46 | 0.50 | 3.40 | 3.53 | 3.45 | 3.58 | 1.38 | 1.38 | 1.42 | 1.47 |
| $D_3V_4$ | 0.53 | 0.56 | 0.46 | 0.50 | 3.40 | 3.53 | 3.45 | 3.58 | 1.38 | 1.38 | 1.42 | 1.45 |
| $D_3V_5$ | 0.56 | 0.58 | 0.48 | 0.55 | 1.27 | 1.38 | 1.51 | 1.57 | 0.51 | 0.53 | 0.64 | 0.63 |
| $D_4V_1$ | 0.47 | 0.49 | 0.48 | 0.56 | 3.37 | 3.50 | 3.31 | 3.44 | 1.38 | 1.44 | 1.39 | 1.43 |
| $D_4V_2$ | 0.47 | 0.49 | 0.48 | 0.56 | 3.37 | 3.50 | 3.31 | 3.44 | 1.38 | 1.44 | 1.39 | 1.43 |
| $D_4V_3$ | 0.5 | 0.5 | 0.48 | 0.56 | 3.10 | 3.21 | 3.31 | 3.44 | 1.35 | 1.31 | 1.34 | 1.33 |
| $D_4V_4$ | 0.47 | 0.49 | 0.48 | 0.56 | 3.37 | 3.50 | 3.31 | 3.44 | 1.35 | 1.36 | 1.34 | 1.33 |
| $D_4V_5$ | 0.53 | 0.66 | 0.62 | 0.70 | 1.49 | 1.55 | 1.34 | 1.4 | 0.59 | 0.61 | 0.53 | 0.55 |
| **Mean** | **0.64** | **0.67** | **0.61** | **0.66** | **2.99** | **3.09** | **3.04** | **3.14** | **1.21** | **1.24** | **1.23** | **1.26** |
| **RMSE** | **0.04** | | **0.05** | | **0.12** | | **0.12** | | **0.04** | | **0.08** | |
| **CRM** | **-5.35** | | **-8.44** | | **-3.53** | | **-3.48** | | **-2.64** | | **-1.41** | |

DAS : Days after sowing

M : Measured; S : Simulated

RMSE : Root mean square error; CRM : Coefficient of residual mass

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH -1 ; $V_3$ = DMH – 2

$V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight

$D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight

**Table 41. Measured and simulated days to 50 per cent flowering and physiological maturity of maize varieties as influenced by planting dates**

| Treatments | Days to flowering | | | | Days to physiological maturity | | | |
|---|---|---|---|---|---|---|---|---|
| | 1998-99 | | 1999-2000 | | 1998-99 | | 1999-2000 | |
| | M | S | M | S | M | S | M | S |
| $D_1V_1$ | 69 | 68 | 70 | 70 | 136 | 135 | 135 | 134 |
| $D_1V_2$ | 69 | 68 | 70 | 70 | 136 | 135 | 135 | 134 |
| $D_1V_3$ | 66 | 65 | 66 | 66 | 139 | 138 | 138 | 137 |
| $D_1V_4$ | 69 | 68 | 70 | 70 | 136 | 136 | 135 | 134 |
| $D_1V_5$ | 48 | 47 | 47 | 46 | 104 | 105 | 101 | 100 |
| $D_2V_1$ | 69 | 68 | 70 | 69 | 131 | 131 | 131 | 130 |
| $D_2V_2$ | 69 | 68 | 70 | 69 | 131 | 131 | 131 | 130 |
| $D_2V_3$ | 69 | 68 | 70 | 69 | 136 | 135 | 135 | 135 |
| $D_2V_4$ | 69 | 68 | 70 | 69 | 131 | 131 | 131 | 130 |
| $D_2V_5$ | 47 | 46 | 48 | 47 | 102 | 103 | 99 | 100 |
| $D_3V_1$ | 74 | 73 | 71 | 71 | 129 | 128 | 128 | 128 |
| $D_3V_2$ | 74 | 73 | 71 | 71 | 129 | 128 | 128 | 128 |
| $D_3V_3$ | 74 | 73 | 71 | 71 | 133 | 132 | 134 | 133 |
| $D_3V_4$ | 74 | 73 | 71 | 71 | 129 | 128 | 130 | 129 |
| $D_3V_5$ | 45 | 46 | 52 | 51 | 100 | 100 | 100 | 100 |
| $D_4V_1$ | 74 | 73 | 70 | 69 | 123 | 124 | 124 | 124 |
| $D_4V_2$ | 74 | 73 | 70 | 69 | 123 | 124 | 124 | 124 |
| $D_4V_3$ | 71 | 70 | 70 | 69 | 127 | 126 | 128 | 128 |
| $D_4V_4$ | 74 | 73 | 70 | 69 | 124 | 124 | 124 | 124 |
| $D_4V_5$ | 52 | 52 | 49 | 48 | 99 | 100 | 95 | 95 |
| **MEAN** | **66.50** | **65.65** | **65.80** | **65.20** | **124.8** | **124.7** | **124.2** | **123.85** |
| **RMSE** | **0.95** | | **0.78** | | **0.84** | | **0.74** | |
| **CRM** | **1.20** | | **0.91** | | **0.16** | | **0.36** | |

M : Measured; S : Simulated

RMSE : Root mean square error; CRM : Coefficient of residual mass

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH -1 ; $V_3$ = DMH – 2

$V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight

$D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight

### 4.3.2.4 Yield and yield parameters

#### 4.3.2.4.1 Measured v/s simulated grain yield (kg ha$^{-l}$) (cf. Table 42)

The measured and simulated mean grain yield was 6214 and 6325 kg ha$^{-l}$ during 1998-99, and 6729 and 6810 kg ha$^{-l}$ during 1999- 2000 respectively. Corresponding to the seasons the RMSE and CRM values were 154.84 and -1.78, and 197.84 and -1.21 respectively. Based on the statistical measurement it was observed that the grain yield variation between measured and CERES maize simulated was in the range of 154.84 to 197.84 kg ha$^{-l}$. And, the CRM values were between -1.78 and -1.21. The CERES-maize model overestimated the grain yield to an extent of 1.78 per cent during 1998- 99 and 1.21 per cent during 1999-2000.

#### 4.3.2.4.2 Measured v/s simulated stover yield (kg ha$^{-l}$) (cf. Table 42)

The measured and CERES-maize simulated mean stover yield was 7163 and 7436 kg ha$^{-l}$ during 1998-99, and 7206 and 7468 kg ha$^{-1}$ during 1999-2000. The RMSE and CRM values for the corresponding seasons were 287.72 and -3.81, and 266.39 and -3.64 respectively. The stover yield variation was between 287.72 to 266.39 kg ha$^{-l}$. Further, the CRM values were between -3.81 to -3.64, the results indicated that the model overestimated the stover yield to the extent of 3.21 to 3.64 per cent during 1998-99 and 1999-2000 seasons respectively.

#### 4.3.2.4.3 Measured v/s simulated biomass yield (kg ha$^{-l}$) (cf. Table 42)

The measured and CERES-maize simulated biomass yield for the year 1998-99 was 13377 and 13761 kg ha$^{-l}$ and for the year 1999-2000 was 13935 and 14278 kg ha$^{-l}$ respectively. During the year 1998-99 RMSE and CRM values were 380.27 and -2.66, during 1999-2000 RMSE and CRM values were 395.59 and -2.47 respectively. The variation between measured and simulated biomass yield was between 380.27 and 397.59 kg ha$^{-l}$. As the CRM values were between -2.66 and -2.47, CERES-maize model overestimated the biomass yield to the extent of 2.66 and 2.47 per cent during 1998-99 and 1999-2000 respectively.

#### 4.3.2.4.4 Measured v/s simulated harvest index (cf. Table 42)

The field experimentation and CERES maize simulated harvest index mean values during 1998-99 were 0.460 and 0.456, and during- 1999-2000 were 0.478 and 0.472, corresponding to the seasons the RMSE was 0.0066 and 0.0094, and CRM was 1.03 and 1.43 respectively. The harvest index variation between measured and simulated was 0.0066 to 0.0094. And, based on the CRM values the CERES-maize under predicted the harvest index to the extent of 1.03 and 1.43 per cent during 1998-99 and 1999-2000 respectively.

#### 4.3.2.4.5 Measured v/s simulated grain weight (mg grain$^{-1}$) (cf. Table 43)

The measured and simulated mean grain weight was 262 and 253 mg grain$^{-1}$ during 1998-99, while during 1999-2000 the values were 263 and 256 mg grain$^{-1}$ respectively. Correspondingly, the RMSE and CRM data were 10.44 and 7.87 and 3.43 and 2.59 respectively. The variation between measured and simulated was in the range of 7.86 to 10.44 mg grain$^{-1}$. The CERES-maize model underestimated the grain weight in the range of 2.59 to 3.43 per cent.

#### 4.3.2.4.6 Measured v/s simulated grains ear$^{-1}$ (cf. Table 43)

The mean values for measured and simulated grains ear$^{-1}$ were 424 and 450 during 1998-99, and 451 and 477 during 1999- 2000. The RMSE and CRM values were 26 and 26.34, and -6.09 and -5.76 for 1998-99 and 1999-2000 respectively. The RMSE values showed that the variation was in the range of 26 to 26.34 grains ear$^{-1}$. The model over predicted the grains ear$^{-1}$ in the range of 5.76 to 6.09 per cent.

#### 4.3.2.4.7 Measured v/s simulated grain number m$^{-2}$ (cf. Table 43)

The average values for the measured and simulated grain number m$^{-2}$ were 2340 and 2473 during 1998-99, 2495 and 2624 during 1999- 2000 seasons respectively. Corresponding to the seasons, the RMSE and CRM values 130.63 and 130.63, and -5.69 and -5.18 respectively. The variation was 130.63 grain number m$^{-2}$. The tendency of the model was overestimation in the range between 5.18 and 5.69 per cent during 1999-2000 and 1998-99 respectively.

Table 42. Measured and simulated grain yield, stover yield , biomass yield and harvest index of maize varieties as influenced by planting dates

| Treatments | Grain yield( kg ha$^{-1}$ ) | | | | Stover yield( kg ha$^{-1}$ ) | | | | Biomass yield ( kg ha$^{-1}$ ) | | | | Harvest index | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-99 | | 1999-2000 | | 1998-99 | | 1999-2000 | | 1998-99 | | 1999-2000 | | 1998-99 | | 1999-2000 | |
| | M | S | M | S | M | S | M | S | M | S | M | S | M | S | M | S |
| $D_1V_1$ | 6634 | 6878 | 7009 | 6928 | 8040 | 8316 | 8008 | 8333 | 14674 | 15194 | 15017 | 15261 | 0.452 | 0.453 | 0.467 | 0.454 |
| $D_1V_2$ | 7531 | 7787 | 7798 | 7845 | 8042 | 8316 | 8011 | 8327 | 15573 | 16103 | 15809 | 16172 | 0.484 | 0.484 | 0.493 | 0.485 |
| $D_1V_3$ | 8116 | 8317 | 8394 | 8595 | 7648 | 7916 | 7698 | 7967 | 15764 | 16233 | 16092 | 16562 | 0.515 | 0.512 | 0.522 | 0.519 |
| $D_1V_4$ | 6428 | 6373 | 6474 | 6421 | 8048 | 8316 | 7997 | 8333 | 14476 | 14689 | 14471 | 14754 | 0.444 | 0.434 | 0.447 | 0.435 |
| $D_1V_5$ | 4137 | 4121 | 4006 | 3802 | 5252 | 5490 | 4779 | 4946 | 9389 | 9611 | 8785 | 8748 | 0.441 | 0.429 | 0.456 | 0.435 |
| $D_2V_1$ | 6532 | 6746 | 7088 | 7058 | 7484 | 7760 | 7842 | 8104 | 14016 | 14506 | 14930 | 15162 | 0.466 | 0.465 | 0.475 | 0.466 |
| $D_2V_2$ | 7524 | 7640 | 7892 | 7996 | 7651 | 7760 | 7796 | 8038 | 15175 | 15400 | 15688 | 16034 | 0.496 | 0.496 | 0.503 | 0.499 |
| $D_2V_3$ | 8320 | 8499 | 8786 | 8901 | 7370 | 7642 | 7633 | 7893 | 15690 | 16141 | 16419 | 16794 | 0.530 | 0.527 | 0.535 | 0.530 |
| $D_2V_4$ | 6317 | 6253 | 6531 | 6544 | 7498 | 7760 | 7828 | 8104 | 13815 | 14013 | 14359 | 14648 | 0.457 | 0.446 | 0.455 | 0.447 |
| $D_2V_5$ | 3487 | 3397 | 3820 | 3706 | 4491 | 4660 | 4856 | 5024 | 7978 | 8057 | 8676 | 8730 | 0.437 | 0.422 | 0.440 | 0.424 |
| $D_3V_1$ | 6133 | 6247 | 6922 | 6927 | 7898 | 8187 | 7959 | 8241 | 14031 | 14434 | 14881 | 15168 | 0.437 | 0.428 | 0.465 | 0.457 |
| $D_3V_2$ | 6720 | 6941 | 7706 | 7848 | 7919 | 8187 | 7938 | 8224 | 14639 | 15128 | 15644 | 16072 | 0.459 | 0.459 | 0.493 | 0.488 |
| $D_3V_3$ | 7562 | 7799 | 8465 | 8563 | 7867 | 8147 | 7830 | 8118 | 15429 | 15946 | 16295 | 16681 | 0.490 | 0.489 | 0.519 | 0.513 |
| $D_3V_4$ | 5811 | 5822 | 6389 | 6422 | 7896 | 8185 | 7966 | 8241 | 13707 | 14007 | 14355 | 14663 | 0.424 | 0.416 | 0.445 | 0.438 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $D_3V_5$ | 3416 | 3490 | 3724 | 3672 | 4505 | 4687 | 5120 | 5311 | 7921 | 8177 | 8844 | 8983 | 0.431 | 0.427 | 0.421 | 0.409 |
| $D_4V_1$ | 6109 | 6277 | 6997 | 7212 | 7768 | 8059 | 7795 | 8073 | 13877 | 14336 | 14792 | 15285 | 0.440 | 0.438 | 0.473 | 0.473 |
| $D_4V_2$ | 6961 | 7113 | 7930 | 8175 | 7777 | 8059 | 7697 | 7986 | 14738 | 15172 | 15627 | 16161 | 0.472 | 0.469 | 0.507 | 0.506 |
| $D_4V_3$ | 7389 | 7400 | 8492 | 9172 | 7382 | 7651 | 7456 | 7702 | 14771 | 15051 | 15948 | 16874 | 0.500 | 0.492 | 0.532 | 0.544 |
| $D_4V_4$ | 5807 | 5970 | 6637 | 6853 | 7776 | 8056 | 7774 | 8070 | 13583 | 14026 | 14411 | 14923 | 0.428 | 0.426 | 0.461 | 0.459 |
| $D_4V_5$ | 3348 | 3423 | 3517 | 3564 | 4951 | 5567 | 4134 | 4324 | 8299 | 8990 | 7651 | 7888 | 0.403 | 0.400 | 0.460 | 0.452 |
| **Mean** | **6214** | **6325** | **6729** | **6810** | **7163** | **7436** | **7206** | **7468** | **13377** | **13761** | **13935** | **14278** | **0.460** | **0.456** | **0.478** | **0.472** |
| **RMSE** | 154.84 | | 197.84 | | 287.72 | | 266.39 | | 380.27 | | 395.59 | | 0.00661 | | 0.009486 | |
| **CRM** | -1.78 | | -1.21 | | -3.81 | | -3.64 | | -2.66 | | -2.47 | | 1.03 | | 1.43 | |

M : Measured; S : Simulated; RMSE: Root mean square error; CRM : Coefficient of residual mass

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH -1 ; $V_3$ = DMH – 2, $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight , $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight

**Table 43. Measured and simulated grain weight , grains ear$^{-1}$ and grain number m$^{-2}$ of maize varieties as influenced by planting dates**

| Treatments | Grain weight ( mg ) | | | | Grains ear$^{-1}$ | | | | Grain number m$^{-2}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-99 | | 1999-2000 | | 1998-99 | | 1999-2000 | | 1998-99 | | 1999-2000 | |
| | M | S | M | S | M | S | M | S | M | S | M | S |
| $D_1V_1$ | 298 | 291 | 291 | 280 | 406 | 430 | 425 | 449 | 2229 | 2364 | 2353 | 2472 |
| $D_1V_2$ | 317 | 313 | 310 | 302 | 426 | 452 | 447 | 473 | 2360 | 2485 | 2471 | 2599 |
| $D_1V_3$ | 357 | 349 | 338 | 333 | 409 | 433 | 444 | 469 | 2261 | 2383 | 2454 | 2581 |
| $D_1V_4$ | 272 | 260 | 260 | 250 | 421 | 446 | 441 | 467 | 2329 | 2455 | 2439 | 2567 |
| $D_1V_5$ | 234 | 207 | 216 | 199 | 336 | 362 | 328 | 347 | 1859 | 1992 | 1815 | 1909 |
| $D_2V_1$ | 272 | 268 | 274 | 265 | 432 | 458 | 458 | 484 | 2389 | 2519 | 2530 | 2660 |
| $D_2V_2$ | 298 | 288 | 293 | 286 | 455 | 482 | 481 | 509 | 2514 | 2649 | 2660 | 2798 |
| $D_2V_3$ | 331 | 321 | 325 | 318 | 454 | 482 | 481 | 509 | 2512 | 2649 | 2663 | 2798 |
| $D_2V_4$ | 252 | 239 | 244 | 237 | 449 | 476 | 474 | 503 | 2407 | 2617 | 2626 | 2764 |
| $D_2V_5$ | 216 | 204 | 212 | 199 | 285 | 303 | 328 | 341 | 1580 | 1666 | 1818 | 1910 |
| $D_3V_1$ | 250 | 239 | 268 | 260 | 439 | 465 | 458 | 485 | 2427 | 2559 | 2533 | 2666 |
| $D_3V_2$ | 263 | 258 | 285 | 280 | 462 | 489 | 482 | 510 | 2553 | 2692 | 2667 | 2805 |
| $D_3V_3$ | 294 | 290 | 310 | 305 | 462 | 489 | 482 | 510 | 2554 | 2692 | 2668 | 2805 |
| $D_3V_4$ | 232 | 219 | 239 | 232 | 456 | 483 | 476 | 504 | 2521 | 2659 | 2627 | 2770 |
| $D_3V_5$ | 196 | 191 | 182 | 176 | 313 | 332 | 358 | 379 | 1732 | 1826 | 1981 | 2085 |
| $D_4V_1$ | 232 | 226 | 242 | 243 | 475 | 505 | 510 | 540 | 2631 | 2776 | 2829 | 2969 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $D_4V_2$ | 250 | 244 | 265 | 262 | 501 | 531 | 537 | 568 | 2770 | 2921 | 2969 | 3125 |
| $D_4V_3$ | 288 | 275 | 296 | 294 | 461 | 489 | 537 | 568 | 2550 | 2687 | 2971 | 3125 |
| $D_4V_4$ | 211 | 207 | 224 | 222 | 494 | 524 | 530 | 561 | 2735 | 2884 | 2932 | 3086 |
| $D_4V_5$ | 178 | 172 | 185 | 180 | 340 | 361 | 341 | 361 | 1884 | 1987 | 1886 | 1984 |
| **Mean** | **262** | **253** | **263** | **256** | **424** | **450** | **451** | **477** | **2340** | **2473** | **2495** | **2624** |
| **RMSE** | 10.44 | | 7.87 | | 26.00 | | 26.34 | | 130.63 | | 130.63 | |
| **CRM** | 3.43 | | 2.59 | | -6.09 | | -5.76 | | -5.69 | | -5.18 | |

M : Measured; S : Simulated; RMSE: Root mean square error; CRM : Coefficient of residual mass

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH -1 ; $V_3$ = DMH – 2, $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight, $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight

**Table 44. Measured and simulated water use (mm) of maize varieties as influenced by planting dates.**

| Treatments | 1998-99 | | 1999-2000 | |
|---|---|---|---|---|
| | M | S | M | S |
| $D_1V_1$ | 490.96 | 509.48 | 519.59 | 539.18 |
| $D_1V_2$ | 490.92 | 509.44 | 517.86 | 539.13 |
| $D_1V_3$ | 503.82 | 522.82 | 531.74 | 551.79 |
| $D_1V_4$ | 495.40 | 514.09 | 519.86 | 539.46 |
| $D_1V_5$ | 336.29 | 348.97 | 330.67 | 343.14 |
| $D_2V_1$ | 519.59 | 539.18 | 535.15 | 555.33 |
| $D_2V_2$ | 519.58 | 539.17 | 535.11 | 555.29 |
| $D_2V_3$ | 538.12 | 558.41 | 559.70 | 581.47 |
| $D_2V_4$ | 519.87 | 539.48 | 535.45 | 555.65 |
| $D_2V_5$ | 353.98 | 367.58 | 352.63 | 365.93 |
| $D_3V_1$ | 528.79 | 548.73 | 557.40 | 578.43 |
| $D_3V_2$ | 528.26 | 548.69 | 557.37 | 578.39 |
| $D_3V_3$ | 549.53 | 570.25 | 584.65 | 606.70 |
| $D_3V_4$ | 528.56 | 548.5 | 562.50 | 583.71 |
| $D_3V_5$ | 337.73 | 350.27 | 374.90 | 389.04 |
| $D_4V_1$ | 549.99 | 570.73 | 567.60 | 589.00 |
| $D_4V_2$ | 549.97 | 570.71 | 567.55 | 588.95 |
| $D_4V_3$ | 558.25 | 579.3 | 588.88 | 611.09 |
| $D_4V_4$ | 549.71 | 570.44 | 567.40 | 588.80 |
| $D_4V_5$ | 378.44 | 392.71 | 365.76 | 379.55 |
| **Mean** | **491.39** | **509.95** | **511.59** | **531.00** |
| **RMSE** | 18.76 | | 19.66 | |
| **CRM** | -3.78 | | -3.79 | |

M : Measured; S : Simulated

RMSE : Root mean square error; CRM : Coefficient of residual mass

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH -1 ; $V_3$ = DMH – 2

$V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight

$D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight

**Table 45. Measured and simulated LAI of maize at 30, 60 and 90 DAS as influenced by irrigation scheduling, plant density and nitrogen levels**

| Treatments | 30 DAS | | | | 60 DAS | | | | 90 DAS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-99 | | 1999-2000 | | 1998-99 | | 1999-2000 | | 1998-99 | | 1999-2000 | |
| | M | S | M | S | M | S | M | S | M | S | M | S |
| $I_1P_1N_1$ | 0.63 | 0.67 | 0.6 | 0.64 | 2.8 | 2.97 | 2.66 | 2.82 | 2.76 | 2.92 | 2.28 | 2.95 |
| $I_1P_1N_2$ | 0.64 | 0.67 | 0.6 | 0.63 | 2.81 | 2.95 | 2.59 | 2.84 | 2.77 | 2.95 | 2.58 | 2.63 |
| $I_1P_1N_3$ | 0.65 | 0.67 | 0.61 | 0.63 | 2.83 | 2.93 | 2.72 | 2.83 | 2.77 | 2.88 | 2.46 | 2.55 |
| $I_1P_1N_4$ | 0.65 | 0.67 | 0.61 | 0.63 | 2.81 | 2.91 | 2.71 | 2.82 | 2.76 | 2.86 | 2.44 | 2.53 |
| $I_1P_2N_1$ | 0.95 | 1.01 | 0.84 | 0.9 | 2.85 | 3.70 | 3.17 | 3.36 | 3.55 | 3.77 | 3.03 | 3.22 |
| $I_1P_2N_2$ | 0.96 | 1.00 | 0.84 | 0.88 | 3.59 | 3.72 | 3.37 | 3.53 | 3.56 | 3.65 | 3.03 | 3.19 |
| $I_1P_2N_3$ | 0.97 | 1.00 | 0.85 | 0.88 | 3.46 | 3.59 | 3.36 | 3.49 | 3.21 | 3.32 | 2.78 | 2.89 |
| $I_1P_2N_4$ | 0.97 | 1.00 | 0.85 | 0.88 | 3.42 | 3.55 | 3.32 | 3.45 | 3.16 | 3.25 | 2.73 | 2.84 |
| $I_1P_3N_1$ | 1.21 | 1.22 | 1.02 | 1.10 | 3.83 | 4.06 | 3.55 | 3.77 | 3.76 | 3.99 | 3.23 | 3.42 |
| $I_1P_3N_2$ | 1.17 | 1.21 | 1.01 | 1.05 | 3.95 | 4.14 | 3.89 | 4.08 | 3.81 | 4.00 | 3.51 | 3.68 |
| $I_1P_3N_3$ | 1.18 | 1.20 | 1.02 | 1.05 | 3.76 | 3.91 | 3.92 | 4.08 | 3.39 | 3.52 | 3.42 | 3.35 |
| $I_1P_3N_4$ | 1.18 | 1.20 | 1.02 | 1.05 | 3.69 | 3.84 | 3.91 | 4.00 | 3.30 | 3.43 | 3.13 | 3.25 |
| $I_2P_1N_1$ | 0.64 | 0.67 | 0.60 | 0.64 | 3.02 | 3.08 | 2.93 | 3.05 | 2.90 | 3.02 | 2.88 | 3.00 |
| $I_2P_1N_2$ | 0.65 | 0.67 | 0.61 | 0.63 | 3.02 | 3.13 | 2.96 | 3.07 | 2.99 | 3.10 | 2.95 | 3.06 |
| $I_2P_1N_3$ | 0.65 | 0.67 | 0.61 | 0.63 | 3.03 | 3.13 | 2.97 | 3.07 | 3.01 | 3.10 | 2.96 | 3.06 |
| $I_2P_1N_4$ | 0.65 | 0.67 | 0.61 | 0.63 | 3.03 | 3.13 | 2.97 | 3.07 | 3.01 | 3.09 | 2.97 | 3.06 |
| $I_2P_2N_1$ | 0.97 | 1.01 | 0.85 | 0.9 | 3.97 | 4.14 | 3.84 | 4.01 | 3.89 | 4.06 | 3.80 | 3.97 |
| $I_2P_2N_2$ | 0.97 | 1.00 | 0.85 | 0.88 | 4.12 | 4.27 | 4.00 | 4.15 | 4.12 | 4.27 | 4.07 | 4.21 |
| $I_2P_2N_3$ | 0.97 | 1.00 | 0.85 | 0.88 | 4.16 | 4.26 | 4.05 | 4.15 | 4.17 | 4.27 | 4.11 | 4.22 |
| $I_2P_2N_4$ | 0.97 | 1.00 | 0.85 | 0.88 | 4.17 | 4.26 | 4.06 | 4.15 | 4.17 | 4.27 | 4.13 | 4.22 |
| $I_2P_3N_1$ | 1.21 | 1.28 | 1.03 | 1.10 | 4.36 | 4.68 | 4.46 | 4.65 | 4.20 | 4.39 | 4.22 | 4.41 |
| $I_2P_3N_2$ | 1.19 | 1.21 | 1.02 | 1.05 | 4.65 | 4.82 | 4.66 | 4.84 | 4.32 | 4.49 | 4.38 | 4.54 |
| $I_2P_3N_3$ | 1.19 | 1.20 | 1.02 | 1.05 | 4.70 | 4.81 | 4.72 | 4.84 | 4.40 | 4.50 | 4.42 | 4.55 |
| $I_2P_3N_4$ | 1.19 | 1.20 | 1.02 | 1.05 | 4.70 | 4.8 | 4.72 | 4.84 | 4.41 | 4.50 | 4.45 | 4.55 |
| $I_3P_1N_1$ | 0.64 | 0.67 | 0.6 | 0.64 | 2.95 | 3.08 | 2.94 | 3.08 | 2.89 | 3.01 | 2.90 | 3.02 |
| $I_3P_1N_2$ | 0.65 | 0.67 | 0.61 | 0.63 | 3.02 | 3.13 | 3.00 | 3.11 | 2.99 | 3.10 | 2.98 | 3.09 |
| $I_3P_1N_3$ | 0.65 | 0.67 | 0.61 | 0.63 | 3.03 | 3.13 | 3.63 | 3.11 | 3.00 | 3.10 | 2.99 | 3.09 |
| $I_3P_1N_4$ | 0.65 | 0.67 | 0.61 | 0.63 | 3.02 | 3.13 | 3.02 | 3.11 | 3.01 | 3.10 | 2.99 | 3.09 |
| $I_3P_2N_1$ | 0.97 | 1.01 | 0.86 | 0.9 | 4.10 | 4.27 | 4.04 | 4.21 | 3.99 | 4.16 | 3.94 | 4.10 |
| $I_3P_2N_2$ | 0.97 | 1.00 | 0.88 | 0.88 | 4.29 | 4.46 | 4.18 | 4.35 | 4.18 | 4.35 | 4.19 | 4.34 |
| $I_3P_2N_3$ | 0.97 | 1.00 | 0.85 | 0.88 | 4.34 | 4.45 | 4.24 | 4.35 | 4.24 | 4.35 | 4.24 | 4.34 |
| $I_3P_2N_4$ | 0.97 | 1.00 | 0.85 | 0.88 | 4.35 | 4.45 | 4.25 | 4.35 | 4.25 | 4.35 | 4.25 | 4.34 |
| $I_3P_3N_1$ | 1.20 | 1.28 | 1.04 | 1.10 | 4.73 | 4.94 | 4.27 | 4.91 | 4.26 | 4.45 | 4.22 | 4.46 |
| $I_3P_3N_2$ | 1.18 | 1.21 | 1.03 | 1.05 | 4.94 | 5.13 | 4.92 | 5.11 | 4.39 | 4.56 | 4.38 | 4.59 |
| $I_3P_3N_3$ | 1.18 | 1.20 | 1.02 | 1.05 | 5.00 | 5.12 | 4.97 | 5.11 | 4.46 | 4.58 | 4.42 | 4.61 |
| $I_3P_3N_4$ | 1.18 | 1.20 | 1.02 | 1.05 | 5.01 | 5.12 | 4.99 | 5.11 | 4.44 | 4.58 | 4.45 | 4.61 |
| **Mean** | **0.93** | **0.96** | **0.83** | **0.86** | **3.76** | **3.92** | **3.72** | **3.86** | **3.62** | **3.76** | **3.50** | **3.64** |
| **RMSE** | **0.03** | | **0.04** | | **0.20** | | **0.20** | | **0.14** | | **0.17** | |
| **CRM** | **-3.15** | | **-4.00** | | **-3.99** | | **-3.67** | | **-3.68** | | **-3.88** | |

DAS : Days after sowing

M : Measured; S : Simulated

RMSE : Root mean square error; CRM : Coefficient of residual mass

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density (P) : $P_1$ = 55555 Plants $ha^{-1}$; $P_2$ = 83333 Plants $ha^{-1}$; $P_3$ = 111111 Plants $ha^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg $ha^{-1}$; $N_2$ = 150 Kg $ha^{-1}$; $N_3$ = 225 Kg $ha^{-1}$; $N_4$ = 300 Kg $ha^{-1}$

**Table 46. Measured and simulated LAI of maize at 120 DAS and at physiological maturity as influenced by irrigation scheduling, plant density and nitrogen levels**

| Treatments | 120 DAS | | | | Physiological maturity | | | |
|---|---|---|---|---|---|---|---|---|
| | 1998-99 | | 1999-2000 | | 1998-99 | | 1999-2000 | |
| | M | S | M | S | M | S | M | S |
| $I_1P_1N_1$ | 1.78 | 1.88 | 1.64 | 1.74 | 1.23 | 1.31 | 1.25 | 1.32 |
| $I_1P_1N_2$ | 1.79 | 1.87 | 1.64 | 1.72 | 1.56 | 1.30 | 1.25 | 1.31 |
| $I_1P_1N_3$ | 1.78 | 1.85 | 1.66 | 1.72 | 1.23 | 1.29 | 1.25 | 1.3 |
| $I_1P_1N_4$ | 1.78 | 1.85 | 1.65 | 1.71 | 1.14 | 1.29 | 1.24 | 1.29 |
| $I_1P_2N_1$ | 2.29 | 2.43 | 2.06 | 2.19 | 1.60 | 1.70 | 1.56 | 1.66 |
| $I_1P_2N_2$ | 2.34 | 2.45 | 2.15 | 2.26 | 1.63 | 1.71 | 1.64 | 1.71 |
| $I_1P_2N_3$ | 2.30 | 2.39 | 1.94 | 2.02 | 1.59 | 1.67 | 1.63 | 1.69 |
| $I_1P_2N_4$ | 2.28 | 2.37 | 1.93 | 2.00 | 1.58 | 1.66 | 1.61 | 1.67 |
| $I_1P_3N_1$ | 2.64 | 2.80 | 2.42 | 2.56 | 1.80 | 1.95 | 1.8 | 1.94 |
| $I_1P_3N_2$ | 2.72 | 2.85 | 2.58 | 2.71 | 1.88 | 1.99 | 1.95 | 2.05 |
| $I_1P_3N_3$ | 2.55 | 2.65 | 2.22 | 2.31 | 1.81 | 1.92 | 1.83 | 1.92 |
| $I_1P_3N_4$ | 2.51 | 2.60 | 2.16 | 2.24 | 1.79 | 1.90 | 1.79 | 1.87 |
| $I_2P_1N_1$ | 1.87 | 1.95 | 1.76 | 1.86 | 1.31 | 1.36 | 1.35 | 1.41 |
| $I_2P_1N_2$ | 1.93 | 2.00 | 1.83 | 1.90 | 1.34 | 1.39 | 1.36 | 1.43 |
| $I_2P_1N_3$ | 1.94 | 2.00 | 1.83 | 1.89 | 1.35 | 1.39 | 1.37 | 1.43 |
| $I_2P_1N_4$ | 1.94 | 2.00 | 1.84 | 1.90 | 1.36 | 1.39 | 1.37 | 1.43 |
| $I_2P_2N_1$ | 2.52 | 2.62 | 2.36 | 2.46 | 1.71 | 1.83 | 1.77 | 1.86 |
| $I_2P_2N_2$ | 2.86 | 2.77 | 2.51 | 2.61 | 1.85 | 1.93 | 1.90 | 1.97 |
| $I_2P_2N_3$ | 2.71 | 2.77 | 2.55 | 2.61 | 1.93 | 1.93 | 1.92 | 1.98 |
| $I_2P_2N_4$ | 2.73 | 2.76 | 2.56 | 2.61 | 1.94 | 1.93 | 1.93 | 1.98 |
| $I_2P_3N_1$ | 2.96 | 3.09 | 2.82 | 2.14 | 2.08 | 2.16 | 2.13 | 2.23 |
| $I_2P_3N_2$ | 3.17 | 3.29 | 3.08 | 3.19 | 2.22 | 2.30 | 2.33 | 2.42 |
| $I_2P_3N_3$ | 3.21 | 3.31 | 3.13 | 3.21 | 2.30 | 2.31 | 2.39 | 2.43 |
| $I_2P_3N_4$ | 3.22 | 3.30 | 3.14 | 3.21 | 2.30 | 2.31 | 2.39 | 2.43 |
| $I_3P_1N_1$ | 1.86 | 1.94 | 1.79 | 1.87 | 1.31 | 1.36 | 1.34 | 1.41 |
| $I_3P_1N_2$ | 1.93 | 2.00 | 1.85 | 1.92 | 1.37 | 1.39 | 1.38 | 1.45 |
| $I_3P_1N_3$ | 1.94 | 2.00 | 1.86 | 1.91 | 1.38 | 1.39 | 1.38 | 1.45 |
| $I_3P_1N_4$ | 1.94 | 2.00 | 1.86 | 1.91 | 1.38 | 1.39 | 1.39 | 1.45 |
| $I_3P_2N_1$ | 2.56 | 2.68 | 2.44 | 2.54 | 1.73 | 1.87 | 1.82 | 1.92 |
| $I_3P_2N_2$ | 2.77 | 2.88 | 2.61 | 2.71 | 1.93 | 2.01 | 1.96 | 2.05 |
| $I_3P_2N_3$ | 2.81 | 2.88 | 2.65 | 2.72 | 2.16 | 2.01 | 2.01 | 2.06 |
| $I_3P_2N_4$ | 2.82 | 2.88 | 2.66 | 2.72 | 2.18 | 2.01 | 2.02 | 2.06 |
| $I_3P_3N_1$ | 3.10 | 3.24 | 2.94 | 3.07 | 2.15 | 2.26 | 2.2 | 2.32 |
| $I_3P_3N_2$ | 3.37 | 3.51 | 3.23 | 3.36 | 2.34 | 2.45 | 2.43 | 2.54 |
| $I_3P_3N_3$ | 3.42 | 3.54 | 3.30 | 3.39 | 2.42 | 2.47 | 2.5 | 2.57 |
| $I_3P_3N_4$ | 3.44 | 3.53 | 3.31 | 3.39 | 2.42 | 2.47 | 2.51 | 2.57 |
| **MEAN** | **2.49** | **2.58** | **2.33** | **2.40** | **1.76** | **1.80** | **1.78** | **1.85** |
| **RMSE** | **0.10** | | **0.14** | | **0.10** | | **0.08** | |
| **CRM** | **-3.51** | | **-2.76** | | **-2.69** | | **-4.11** | |

DAS : Days after sowing

M : Measured; S : Simulated

RMSE : Root mean square error; CRM : Coefficient of residual mass

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density (P) : $P_1$ = 55555 Plants $ha^{-1}$; $P_2$ = 83333 Plants $ha^{-1}$; $P_3$ = 111111 Plants $ha^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg $ha^{-1}$; $N_2$ = 150 Kg $ha^{-1}$; $N_3$ = 225 Kg $ha^{-1}$; $N_4$ = 300 Kg $ha^{-1}$

**Table 47. Measured and simulated grain and stover yield of maize as influenced by irrigation scheduling, plant density and nitrogen levels**

| Treatments | Grain yield ( kg ha $^{-1}$ ) | | | | Stover yield ( kg ha $^{-1}$ ) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1998-99 | | 1999-2000 | | 1998-99 | | 1999-2000 | |
| | M | S | M | S | M | S | M | S |
| $I_1P_1N_1$ | 6005 | 6467 | 6396 | 6872 | 6972 | 7361 | 6684 | 7063 |
| $I_1P_1N_2$ | 6146 | 6566 | 6478 | 6844 | 7158 | 7393 | 6764 | 7092 |
| $I_1P_1N_3$ | 5949 | 6200 | 6079 | 6357 | 7083 | 7341 | 6745 | 6910 |
| $I_1P_1N_4$ | 5943 | 6189 | 6097 | 6323 | 7147 | 7303 | 6724 | 6883 |
| $I_1P_2N_1$ | 5738 | 6175 | 6139 | 6556 | 8916 | 9403 | 8259 | 8749 |
| $I_1P_2N_2$ | 6625 | 7025 | 6806 | 7341 | 9526 | 9989 | 8730 | 9060 |
| $I_1P_2N_3$ | 6081 | 6276 | 6105 | 6420 | 9169 | 9555 | 8507 | 8735 |
| $I_1P_2N_4$ | 5998 | 6232 | 6063 | 6375 | 9113 | 9469 | 8428 | 8648 |
| $I_1P_3N_1$ | 5544 | 5912 | 5962 | 6399 | 9948 | 10541 | 8974 | 9506 |
| $I_1P_3N_2$ | 6765 | 7560 | 6974 | 8040 | 10864 | 11313 | 9965 | 10444 |
| $I_1P_3N_3$ | 6170 | 6520 | 6497 | 6831 | 10128 | 10504 | 9699 | 10065 |
| $I_1P_3N_4$ | 6087 | 6443 | 6386 | 6697 | 10030 | 10403 | 9591 | 9923 |
| $I_2P_1N_1$ | 6554 | 6925 | 7162 | 7693 | 6989 | 7268 | 6691 | 6941 |
| $I_2P_1N_2$ | 7106 | 7141 | 7936 | 7968 | 7797 | 8059 | 7791 | 7998 |
| $I_2P_1N_3$ | 7147 | 7141 | 7994 | 7968 | 7880 | 8065 | 7713 | 8001 |
| $I_2P_1N_4$ | 7139 | 7140 | 7848 | 7968 | 7903 | 8064 | 7795 | 8003 |
| $I_2P_2N_1$ | 6013 | 6355 | 6333 | 6693 | 9350 | 9723 | 9247 | 9608 |
| $I_2P_2N_2$ | 7595 | 7900 | 8351 | 8782 | 11132 | 11500 | 10585 | 10987 |
| $I_2P_2N_3$ | 8140 | 8140 | 8809 | 8860 | 11418 | 11586 | 10859 | 11056 |
| $I_2P_2N_4$ | 8179 | 8169 | 8850 | 8860 | 11505 | 11582 | 11219 | 11058 |
| $I_2P_3N_1$ | 5510 | 5817 | 5848 | 6248 | 10785 | 11241 | 10211 | 10647 |
| $I_2P_3N_2$ | 7862 | 8251 | 8683 | 9160 | 12703 | 13140 | 12010 | 12454 |
| $I_2P_3N_3$ | 8623 | 8542 | 9149 | 9284 | 13025 | 13324 | 12756 | 12658 |
| $I_2P_3N_4$ | 8649 | 8592 | 9139 | 9284 | 13053 | 13318 | 12434 | 12660 |
| $I_3P_1N_1$ | 6525 | 6902 | 7196 | 7652 | 6894 | 7173 | 6575 | 6853 |
| $I_3P_1N_2$ | 7073 | 7142 | 7701 | 7988 | 7797 | 8036 | 7748 | 8022 |
| $I_3P_1N_3$ | 7102 | 7142 | 7887 | 7988 | 7860 | 8067 | 7848 | 8039 |
| $I_3P_1N_4$ | 7159 | 7142 | 7952 | 7988 | 7971 | 8067 | 7884 | 8039 |
| $I_3P_2N_1$ | 5868 | 6198 | 6075 | 6456 | 9280 | 9668 | 9191 | 9589 |
| $I_3P_2N_2$ | 7621 | 7913 | 8350 | 8805 | 11240 | 11662 | 10763 | 11177 |
| $I_3P_2N_3$ | 8245 | 8188 | 8876 | 8889 | 11541 | 11745 | 11345 | 11244 |
| $I_3P_2N_4$ | 8280 | 8188 | 8929 | 8889 | 10919 | 11745 | 11377 | 11244 |
| $I_3P_3N_1$ | 5291 | 5584 | 5657 | 5967 | 10745 | 11164 | 10196 | 10642 |
| $I_3P_3N_2$ | 7793 | 8225 | 8739 | 9125 | 12956 | 13433 | 12235 | 12700 |
| $I_3P_3N_3$ | 8545 | 8571 | 9239 | 9311 | 13553 | 13748 | 12893 | 13004 |
| $I_3P_3N_4$ | 8595 | 8572 | 9248 | 9312 | 13565 | 13747 | 12937 | 13004 |
| **Mean** | **6935** | **7151** | **7443** | **7728** | **9831** | **10158** | **9427** | **9686** |
| **RMSE** | **298.45** | | **358.79** | | **359.25** | | **314** | |
| **CRM** | **-3.12** | | **-3.83** | | **-3.33** | | **-2.75** | |

M : Measured; S : Simulated

RMSE : Root mean square error; CRM : Coefficient of residual mass

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density (P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$; $N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$; $N_4$ = 300 Kg ha$^{-1}$

#### 4.3.2.4.8 Water use (mm) (cf. Table 44)

The measured and simulated mean values of water use were 491.39 and 509.95 mm during 1998-99, 511.59 and 531.00 mm during 1999- 2000 seasons. Corresponding to the seasons, the RMSE and CRM were 18.76 and 19.66, and -3.78 and -3.79 respectively. The variation in water use was between 18.76 and 19.66 mm during 1998-99 and 1999-2000 respectively. The CERES maize model overpredicted the water use in the range between 3.78 and 3.79 per cent.

## 4.3.3 Simulation of irrigation scheduling, plant density and nitrogen levels

#### 4.3.3. 1 Measured v/s simulated leaf area index (cf. Table 45 and 46)

The field experiment values of leaf area index recorded at different growth stages such as 30, 60, 90, 120 DAS and at physiological maturity were compared with CERES maize simulated results. The RMSE ranged from 0.03 to 0.20 which indicated that the deviation was at minimum of 0.03 to maximum of 0.20. The CRM values over the growth stages and years varied from -2.69 to -4.11. This indicated that the CERES-maize model overestimated to the extent of minimum of 2.69 per cent to maximum of 4.11 per cent.

#### 4.3.3.2 Measured v/s simulated grain yield (kg ha$^{-1}$) (cf. Table 47)

The mean of the measured and simulated grain yield for different treatment combinations was 6935 and 7151, and 7443 and 7728 kg ha$^{-l}$ during 1998-99 and 1999-2000 seasons respectively. The RMSE values were 298.45 during 1998-99 and 358.79 during 1999-2000 seasons. The same way the CRM values were -3.12 and -3.83 respectively for the 1998-99 and 1999-2000 seasons. The RMSE values indicated that the variation in grain yield was between 298.45 and 358.79 kg ha$^{-1}$. The CRM values indicated that the model over estimated the grain yield in the range of 3.12 to 3.83 per cent.

#### 4.3.3.3 Measured v/s simulated stover yield (kg ha$^{-l}$) (cf. Table 47)

The average of the measured and simulated stover yield was 9831 and 10158 kg ha$^{-l}$ during 1998-99, and 9427 and 9686 kg ha$^{-1}$ during 1999-2000 season.

The RMSE values ranged between 314 and 359.25, indicated that the variation in stover yield ranged between 314 to 359.25 kg ha$^{-l}$. The CRM values were in the range between -2.75 to -3.33. The CERES maize model overpredicted the stover yield in the range between 2.75 and 3.33 per cent.

#### 4.3.3.4 Measured v/s simulated biomass yield (kg ha$^{-l}$) (cf. Table 48)

The mean value of measured and simulated biomass yield (kg ha$^{-l}$) was 16766 and 17310 kg ha$^{-1}$, and 16870 and 17414 kg ha$^{-l}$ during 1998-99 and 1999-2000 seasons respectively. The RMSE values, over the years were in the range of 624.43 to 656.86. The variation between measured and simulated was in the range of 624.43 to 656.86 kg ha$^{-l}$. The CRM values, ranged from -3.24 to -3.26. The CERES-maize model overpredicted the biomass yield in the range of 3.24 to 3.26 per cent.

#### 4.3.3.5 Measured v/s simulated harvest index (cf. Table 48)

The RMSE values over the year was 0.01. This indicated that the variation in harvest index was only 0.01. The CRM values were in the range of 0.04 to -0.50. The CERES maize model overestimated the harvest index to the extent of 0.50 per cent and under estimated to the extent of 0.04 per cent.

#### 4.3.3.6 Measured v/s simulated grain weight (mg grain$^{-1}$) (cf. Table 49)

The mean of measured and simulated grain weight was 272 and 269, and 280 and 277 during 1998-99 and 1999-2000 respectively. The RMSE and CRM ranged between 5.54 and 6.20, and 0.77 and 0.54 during 1998-99 and 1999-2000 seasons respectively. The variation between measured and simulated was in the range of 5.54 to 6.20 mg grain$^{-1.}$ The CRM values showed that the CERES- maize model under predicated the grain weight in the range of 0.54 and 0.77 per cent.

**Table 48. Measured and simulated biomass yield and harvest index of maize as influenced by irrigation scheduling, plant density and nitrogen levels**

| Treatments | Biomass yield ( kg ha$^{-1}$) | | | | Harvest index | | | |
|---|---|---|---|---|---|---|---|---|
| | 1998-99 | | 1999-2000 | | 1998-99 | | 1999-2000 | |
| | M | S | M | S | M | S | M | S |
| $I_1P_1N_1$ | 12977 | 13828 | 13080 | 13935 | 0.463 | 0.468 | 0.489 | 0.493 |
| $I_1P_1N_2$ | 13304 | 13959 | 13242 | 13936 | 0.462 | 0.470 | 0.489 | 0.491 |
| $I_1P_1N_3$ | 13032 | 13541 | 12824 | 13267 | 0.456 | 0.458 | 0.474 | 0.479 |
| $I_1P_1N_4$ | 13090 | 13492 | 12821 | 13206 | 0.454 | 0.459 | 0.476 | 0.479 |
| $I_1P_2N_1$ | 14654 | 15578 | 14398 | 15305 | 0.392 | 0.396 | 0.426 | 0.428 |
| $I_1P_2N_2$ | 16151 | 17014 | 15536 | 16401 | 0.410 | 0.413 | 0.438 | 0.448 |
| $I_1P_2N_3$ | 15250 | 15831 | 14612 | 15155 | 0.399 | 0.396 | 0.418 | 0.424 |
| $I_1P_2N_4$ | 15111 | 15701 | 14491 | 15023 | 0.397 | 0.397 | 0.418 | 0.424 |
| $I_1P_3N_1$ | 15492 | 16453 | 14936 | 15905 | 0.358 | 0.359 | 0.399 | 0.402 |
| $I_1P_3N_2$ | 17629 | 18873 | 16939 | 18484 | 0.384 | 0.401 | 0.412 | 0.435 |
| $I_1P_3N_3$ | 16298 | 17024 | 16196 | 16896 | 0.379 | 0.383 | 0.401 | 0.404 |
| $I_1P_3N_4$ | 16117 | 16846 | 15977 | 16620 | 0.378 | 0.382 | 0.400 | 0.403 |
| $I_2P_1N_1$ | 13543 | 14193 | 13853 | 14634 | 0.484 | 0.488 | 0.517 | 0.526 |
| $I_2P_1N_2$ | 14903 | 15200 | 15727 | 15966 | 0.477 | 0.470 | 0.505 | 0.499 |
| $I_2P_1N_3$ | 15027 | 15206 | 15707 | 15969 | 0.476 | 0.470 | 0.509 | 0.499 |
| $I_2P_1N_4$ | 15042 | 15204 | 15643 | 15971 | 0.475 | 0.470 | 0.502 | 0.499 |
| $I_2P_2N_1$ | 15363 | 16078 | 15580 | 16301 | 0.391 | 0.395 | 0.406 | 0.411 |
| $I_2P_2N_2$ | 18727 | 19400 | 18936 | 19769 | 0.406 | 0.407 | 0.441 | 0.444 |
| $I_2P_2N_3$ | 19558 | 19726 | 19668 | 19916 | 0.416 | 0.413 | 0.448 | 0.445 |
| $I_2P_2N_4$ | 19684 | 19751 | 20069 | 19918 | 0.416 | 0.414 | 0.441 | 0.445 |
| $I_2P_3N_1$ | 16295 | 17058 | 16059 | 16895 | 0.338 | 0.341 | 0.364 | 0.370 |
| $I_2P_3N_2$ | 20565 | 21391 | 20693 | 21614 | 0.382 | 0.386 | 0.420 | 0.424 |
| $I_2P_3N_3$ | 21648 | 21866 | 21905 | 21942 | 0.398 | 0.391 | 0.418 | 0.423 |
| $I_2P_3N_4$ | 21702 | 21910 | 21573 | 21944 | 0.399 | 0.392 | 0.424 | 0.423 |
| $I_3P_1N_1$ | 13419 | 14075 | 13771 | 14505 | 0.486 | 0.490 | 0.523 | 0.528 |
| $I_3P_1N_2$ | 14870 | 15178 | 15449 | 16010 | 0.476 | 0.471 | 0.498 | 0.499 |
| $I_3P_1N_3$ | 14962 | 15209 | 15735 | 16027 | 0.475 | 0.470 | 0.501 | 0.498 |
| $I_3P_1N_4$ | 15130 | 15209 | 15836 | 16027 | 0.473 | 0.470 | 0.502 | 0.498 |
| $I_3P_2N_1$ | 15148 | 15866 | 15266 | 16045 | 0.387 | 0.391 | 0.398 | 0.402 |
| $I_3P_2N_2$ | 18861 | 19575 | 19113 | 19982 | 0.404 | 0.404 | 0.437 | 0.441 |
| $I_3P_2N_3$ | 19786 | 19933 | 20221 | 20133 | 0.417 | 0.411 | 0.439 | 0.442 |
| $I_3P_2N_4$ | 19199 | 19933 | 20306 | 20133 | 0.431 | 0.411 | 0.440 | 0.442 |
| $I_3P_3N_1$ | 16036 | 16748 | 15853 | 16609 | 0.330 | 0.333 | 0.357 | 0.359 |
| $I_3P_3N_2$ | 20749 | 21658 | 20974 | 21825 | 0.376 | 0.380 | 0.417 | 0.418 |
| $I_3P_3N_3$ | 22098 | 22319 | 22132 | 22315 | 0.387 | 0.384 | 0.417 | 0.417 |
| $I_3P_3N_4$ | 22160 | 22319 | 22185 | 22316 | 0.388 | 0.384 | 0.417 | 0.417 |
| **Mean** | **16766** | **17310** | **16870** | **17414** | **0.417** | **0.417** | **0.444** | **0.447** |
| **RMSE** | **624.43** | | **656.86** | | **0.01** | | **0.01** | |
| **CRM** | **-3.26** | | **-3.24** | | **0.04** | | **-0.50** | |

M : Measured; S : Simulated

RMSE : Root mean square error; CRM : Coefficient of residual mass

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density (P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$; $N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$; $N_4$ = 300 Kg ha$^{-1}$

#### 4.3.3.7 Measured v/s simulated grains ear$^{-1}$(cf. Table 49)

The mean values of measured and simulated grains ear$^{-1}$ were 332 and 347, and 357 and 366 during 1998-99 and 1999-2000 respectively. Over the years, the RMSE values ranged from 22.98 to 28.67 and CRM values ranged from -2.52 to -4.51. The variation in grains ear$^{-1}$ was in the range of 22.98 to 28.67 grains ear$^{-1}$. The CRM values indicated that the CERES-maize model overpredicted the values in the range of 2.52 to 4.51 per cent.

#### 4.3.3.8 Measured v/s simulated grain number m$^{-2}$ (cf. Table 49)

Over the years, the mean measured and simulated values ranged from 2642 to 2675, and 2783 and 2817 grain number m$^{-2}$ during 1998-99 and 1999-2000 respectively. The RMSE values ranged from 89.49 to 98.64. The variation between measured and simulated grain number m$^{-2}$ was in the range of 89.49 to 98.64 grain number m$^{-2}$. The CRM values were in the range of -1.25 to -1.63. The CERES- maize model overpredicted in the range of 1.25 to 1.63 per cent.

#### 4.3.3.9 Measured v/s simulated water use (mm) (cf. Table 50)

The RMSE values for water use between measured and simulated ranged from 14.45 to 13.75. These values indicated that the variation was between 13.75 to 14.45 mm. The CRM value were in the range of -2.88 to –3.02. The CERES-maize model overpredicted the water use in the range of 2.88 to 3.02 per cent.

#### 4.3.3.10 Measured v/s simulated crop nitrogen uptake (kg ha$^{-l}$) (cf. Table 51)

The root mean square error (RMSE) for crop nitrogen uptake value between measured and simulated was 8.61 and 8.65. The variation was between 8.61 and 8.65 kg ha$^{-1}$. The CRM values indicated negative deviation ranged between -5.41 and -5.53. The CERES-maize model overpredicted the crop nitrogen uptake to the extent of 5.41 to 5.53 per cent.

#### 4.3.3.11 Simulated drainage (cf. Table 52)

The simulated drainage differed due to the effect of irrigation scheduling, plant density and nitrogen level during both the years. The trend was similar.

The simulated drainage increased from 56.24 to 206.30 mm with increase in irrigation scheduling from $I_1$ to $I_3$. The difference due to increase in drainage between $I_1$ and $I_2$, $I_2$ and $I_3$ was 26.95 mm and 123.11 mm respectively.

The increase in plant density from $P_1$ to $P_3$ decreased the drainage. The decrease in drainage was from 118.76 mm at $P_1$ to 112.48 mm at $P_3$. The difference in reduction in drainage between $P_1$ and $P_2$, $P_2$ and $P_3$ was, 4.28 mm and 2.00 mm respectively.

Due to increase in nitrogen from $N_1$ to $N_4$ the drainage loss was also increased marginally from 114.89 mm to 115.56 mm respectively.

The interaction effect due to irrigation scheduling and plant density was differed. The increased plant density from $P_1$ to $P_3$ at $I_1$ irrigation scheduling did not change in the drainage, however at $I_2$ and $I_3$ irrigation level increase in plant density from $P_1$ to $P_3$ decreased the drainage from 88.36 to 79.63 mm, and 211.67 to 201.59 mm respectively. The lower drainage of 56.24 mm at $I_1$ x $P_1$, $I_1$ X $P_2$ and $I_1$ x $P_3$ and higher drainage of 211.67 mm was registered in $I_3$ x $P_1$ interactions.

The drainage differed due to interaction effect of irrigation scheduling and nitrogen level. Irrigation scheduling at $I_1$ with increase in nitrogen from $N_l$ to $N_4$ recorded same drainage loss (56.24 mm). However, irrigation scheduling at $I_2$ and $I_3$ with increase in nitrogen from $N_1$ to $N_4$ increased the drainage loss. The higher drainage of 206.95 mm was recorded at treatment combination of $I_3$ x $N_4$ over others.

The interaction effect of plant density and nitrogen level differed. Though increase in plant density from $P_1$ to $P_3$ at each level of nitrogen had established decrease in the drainage, the increase in nitrogen level from $N_1$ to $N_3$ at $P_{l,}$ and from $N_1$ to $N_4$ at $P_2$ and $P_3$ plant

**Table 49. Measured and simulated grain weight , grains ear$^{-1}$ and grain number m$^{-2}$ of maize as influenced by irrigation scheduling, plant density and nitrogen levels**

| Treat. | Grain weight (mg grain$^{-1}$) | | | | Grains ear$^{-1}$ | | | | Grain number m$^{2}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-99 | | 1999-2000 | | 1998-99 | | 1999-2000 | | 1998-99 | | 1999-2000 | |
| | M | S | M | S | M | S | M | S | M | S | M | S |
| $I_1P_1N_1$ | 261 | 257 | 258 | 258 | 435 | 458 | 465 | 485 | 2387 | 2517 | 2555 | 2667 |
| $I_1P_1N_2$ | 267 | 256 | 257 | 257 | 451 | 466 | 486 | 483 | 2502 | 2564 | 2674 | 2659 |
| $I_1P_1N_3$ | 251 | 242 | 243 | 244 | 451 | 465 | 460 | 474 | 2492 | 2558 | 2612 | 2604 |
| $I_1P_1N_4$ | 251 | 242 | 243 | 244 | 451 | 464 | 466 | 471 | 2483 | 2553 | 2555 | 2588 |
| $I_1P_2N_1$ | 254 | 254 | 257 | 256 | 276 | 293 | 294 | 309 | 2306 | 2431 | 2442 | 2563 |
| $I_1P_2N_2$ | 255 | 255 | 259 | 258 | 319 | 331 | 334 | 343 | 2632 | 2751 | 2788 | 2848 |
| $I_1P_2N_3$ | 240 | 238 | 242 | 240 | 307 | 317 | 313 | 322 | 2563 | 2631 | 2633 | 2672 |
| $I_1P_2N_4$ | 240 | 239 | 240 | 241 | 303 | 314 | 302 | 319 | 2420 | 2604 | 2596 | 2649 |
| $I_1P_3N_1$ | 254 | 255 | 256 | 258 | 198 | 209 | 211 | 223 | 2197 | 2317 | 2358 | 2477 |
| $I_1P_3N_2$ | 255 | 256 | 258 | 259 | 253 | 266 | 270 | 280 | 2816 | 2949 | 2991 | 3104 |
| $I_1P_3N_3$ | 234 | 237 | 235 | 238 | 226 | 247 | 245 | 258 | 2695 | 2741 | 2770 | 2866 |
| $I_1P_3N_4$ | 230 | 238 | 234 | 238 | 221 | 244 | 242 | 253 | 2669 | 2703 | 2732 | 2809 |
| $I_2P_1N_1$ | 274 | 273 | 283 | 286 | 448 | 460 | 474 | 490 | 2457 | 2531 | 2607 | 2694 |
| $I_2P_1N_2$ | 284 | 284 | 292 | 286 | 467 | 474 | 494 | 507 | 2573 | 2609 | 2717 | 2790 |
| $I_2P_1N_3$ | 287 | 281 | 305 | 296 | 473 | 474 | 505 | 507 | 2630 | 2609 | 2830 | 2790 |
| $I_2P_1N_4$ | 287 | 280 | 306 | 296 | 476 | 474 | 515 | 507 | 2641 | 2609 | 2692 | 2791 |
| $I_2P_2N_1$ | 274 | 274 | 286 | 287 | 268 | 279 | 272 | 281 | 2230 | 2314 | 2260 | 2332 |
| $I_2P_2N_2$ | 274 | 276 | 288 | 286 | 273 | 348 | 362 | 371 | 2816 | 2887 | 3002 | 3075 |
| $I_2P_2N_3$ | 283 | 280 | 299 | 291 | 262 | 348 | 383 | 371 | 2989 | 2891 | 3149 | 3082 |
| $I_2P_2N_4$ | 287 | 280 | 304 | 296 | 263 | 348 | 383 | 371 | 2996 | 2890 | 3152 | 3082 |
| $I_2P_3N_1$ | 274 | 275 | 285 | 288 | 184 | 190 | 189 | 196 | 2053 | 2112 | 2097 | 2171 |
| $I_2P_3N_2$ | 274 | 276 | 286 | 286 | 266 | 272 | 279 | 289 | 2954 | 3015 | 3107 | 3208 |
| $I_2P_3N_3$ | 282 | 278 | 298 | 291 | 280 | 275 | 299 | 293 | 3118 | 3048 | 3303 | 3251 |
| $I_2P_3N_4$ | 285 | 278 | 284 | 296 | 281 | 275 | 299 | 293 | 3235 | 3048 | 3315 | 3251 |
| $I_3P_1N_1$ | 274 | 274 | 292 | 287 | 446 | 459 | 473 | 487 | 2453 | 2522 | 2602 | 2680 |
| $I_3P_1N_2$ | 284 | 284 | 304 | 287 | 465 | 475 | 496 | 509 | 2578 | 2610 | 2730 | 2798 |
| $I_3P_1N_3$ | 290 | 284 | 306 | 296 | 475 | 475 | 501 | 509 | 2624 | 2610 | 2740 | 2797 |
| $I_3P_1N_4$ | 292 | 284 | 285 | 296 | 483 | 475 | 386 | 509 | 2660 | 2610 | 2765 | 2797 |
| $I_3P_2N_1$ | 274 | 274 | 289 | 287 | 263 | 272 | 262 | 271 | 2184 | 2256 | 2181 | 2248 |
| $I_3P_2N_2$ | 288 | 284 | 302 | 286 | 276 | 348 | 364 | 372 | 2689 | 2856 | 3019 | 3084 |
| $I_3P_2N_3$ | 296 | 284 | 305 | 296 | 361 | 350 | 382 | 373 | 2921 | 2892 | 3229 | 3096 |
| $I_3P_2N_4$ | 293 | 284 | 306 | 296 | 352 | 350 | 382 | 373 | 3013 | 2901 | 3235 | 3096 |
| $I_3P_3N_1$ | 274 | 275 | 286 | 288 | 178 | 183 | 180 | 187 | 1978 | 2025 | 2004 | 2071 |
| $I_3P_3N_2$ | 281 | 286 | 286 | 286 | 265 | 271 | 279 | 288 | 2936 | 3006 | 3107 | 3196 |
| $I_3P_3N_3$ | 289 | 286 | 302 | 296 | 282 | 276 | 295 | 294 | 3100 | 3059 | 3311 | 3261 |
| $I_3P_3N_4$ | 286 | 286 | 303 | 296 | 283 | 276 | 296 | 294 | 3111 | 3059 | 3326 | 3261 |
| **Mean** | **272** | **269** | **280** | **277** | **332** | **347** | **357** | **366** | **2642** | **2675** | **2783** | **2817** |
| **RMSE** | **5.54** | | **6.20** | | **28.67** | | **22.98** | | **89.49** | | **98.64** | |
| **CRM** | **0.77** | | **0.54** | | **-4.51** | | **-2.52** | | **-1.25** | | **-1.63** | |

M : Measured; S : Simulated

RMSE : Root mean square error; CRM : Coefficient of residual mass

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density (P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$; $N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$; $N_4$ = 300 Kg ha$^{-1}$

**Table 50. Measured and simulated water use of maize as influenced by irrigation scheduling, plant density and nitrogen levels**

| Treatments | Water used ( mm) | | | |
|---|---|---|---|---|
| | 1998-99 | | 1999-2000 | |
| | M | S | M | S |
| $I_1P_1N_1$ | 411.46 | 433.61 | 390.12 | 414.11 |
| $I_1P_1N_2$ | 411.77 | 429.48 | 395.67 | 409.75 |
| $I_1P_1N_3$ | 392.16 | 405.89 | 375.34 | 385.00 |
| $I_1P_1N_4$ | 391.53 | 405.02 | 374.12 | 384.00 |
| $I_1P_2N_1$ | 414.36 | 437.00 | 394.07 | 415.48 |
| $I_1P_2N_2$ | 415.40 | 433.91 | 400.53 | 416.76 |
| $I_1P_2N_3$ | 388.88 | 401.51 | 371.18 | 381.29 |
| $I_1P_2N_4$ | 388.52 | 401.16 | 367.75 | 380.77 |
| $I_1P_3N_1$ | 412.74 | 435.30 | 394.21 | 415.93 |
| $I_1P_3N_2$ | 418.06 | 436.08 | 403.17 | 418.93 |
| $I_1P_3N_3$ | 384.85 | 398.31 | 368.36 | 379.66 |
| $I_1P_3N_4$ | 383.84 | 397.66 | 365.70 | 377.49 |
| $I_2P_1N_1$ | 461.31 | 478.59 | 468.97 | 484.97 |
| $I_2P_1N_2$ | 467.11 | 478.77 | 474.76 | 485.35 |
| $I_2P_1N_3$ | 466.70 | 478.22 | 475.19 | 484.69 |
| $I_2P_1N_4$ | 466.73 | 478.27 | 475.19 | 484.68 |
| $I_2P_2N_1$ | 470.76 | 488.92 | 472.10 | 494.65 |
| $I_2P_2N_2$ | 479.29 | 489.34 | 480.26 | 495.18 |
| $I_2P_2N_3$ | 483.06 | 489.10 | 483.46 | 494.99 |
| $I_2P_2N_4$ | 483.31 | 488.98 | 483.74 | 494.83 |
| $I_2P_3N_1$ | 473.62 | 492.34 | 474.84 | 498.08 |
| $I_2P_3N_2$ | 479.71 | 492.52 | 486.41 | 498.04 |
| $I_2P_3N_3$ | 485.44 | 492.53 | 488.78 | 498.27 |
| $I_2P_3N_4$ | 485.79 | 492.05 | 490.29 | 497.91 |
| $I_3P_1N_1$ | 464.72 | 483.70 | 476.92 | 491.45 |
| $I_3P_1N_2$ | 469.18 | 484.20 | 481.05 | 491.63 |
| $I_3P_1N_3$ | 471.04 | 484.14 | 481.96 | 491.40 |
| $I_3P_1N_4$ | 471.14 | 484.23 | 482.60 | 491.36 |
| $I_3P_2N_1$ | 476.63 | 494.05 | 485.54 | 501.98 |
| $I_3P_2N_2$ | 482.99 | 494.57 | 489.59 | 501.75 |
| $I_3P_2N_3$ | 484.06 | 494.69 | 492.21 | 501.75 |
| $I_3P_2N_4$ | 487.97 | 494.67 | 492.17 | 501.64 |
| $I_3P_3N_1$ | 481.25 | 500.14 | 493.17 | 507.46 |
| $I_3P_3N_2$ | 488.22 | 500.49 | 496.97 | 506.32 |
| $I_3P_3N_3$ | 491.46 | 500.46 | 498.30 | 506.43 |
| $I_3P_3N_4$ | 493.68 | 500.24 | 498.56 | 506.35 |
| **Mean** | 452.19 | 465.84 | 450.65 | 463.62 |
| **RMSE** | 14.45 | | 13.75 | |
| **CRM** | -3.02 | | -2.88 | |

M : Measured; S : Simulated

RMSE : Root mean square error; CRM : Coefficient of residual mass

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density (P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$; $N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$; $N_4$ = 300 Kg ha$^{-1}$

**Table 51. Measured and simulated nitrogen uptake of maize as influenced by irrigation scheduling, plant density and nitrogen levels**

| Treatments | Nitrogen uptake (kg ha$^{-1}$) | | | |
|---|---|---|---|---|
| | 1998-99 | | 1999-2000 | |
| | M | S | M | S |
| $I_1P_1N_1$ | 85 | 93 | 83 | 91 |
| $I_1P_1N_2$ | 133 | 142 | 135 | 144 |
| $I_1P_1N_3$ | 151 | 159 | 155 | 163 |
| $I_1P_1N_4$ | 151 | 159 | 154 | 162 |
| $I_1P_2N_1$ | 89 | 98 | 87 | 96 |
| $I_1P_2N_2$ | 147 | 157 | 146 | 156 |
| $I_1P_2N_3$ | 167 | 175 | 168 | 177 |
| $I_1P_2N_4$ | 165 | 173 | 168 | 176 |
| $I_1P_3N_1$ | 93 | 102 | 92 | 101 |
| $I_1P_3N_2$ | 156 | 166 | 156 | 166 |
| $I_1P_3N_3$ | 177 | 186 | 186 | 195 |
| $I_1P_3N_4$ | 175 | 184 | 183 | 192 |
| $I_2P_1N_1$ | 88 | 95 | 87 | 94 |
| $I_2P_1N_2$ | 128 | 144 | 139 | 147 |
| $I_2P_1N_3$ | 170 | 178 | 184 | 193 |
| $I_2P_1N_4$ | 170 | 178 | 184 | 193 |
| $I_2P_2N_1$ | 94 | 101 | 93 | 100 |
| $I_2P_2N_2$ | 157 | 165 | 157 | 165 |
| $I_2P_2N_3$ | 204 | 213 | 208 | 217 |
| $I_2P_2N_4$ | 205 | 214 | 220 | 229 |
| $I_2P_3N_1$ | 98 | 105 | 97 | 104 |
| $I_2P_3N_2$ | 168 | 176 | 168 | 176 |
| $I_2P_3N_3$ | 218 | 227 | 221 | 230 |
| $I_2P_3N_4$ | 224 | 234 | 241 | 251 |
| $I_3P_1N_1$ | 85 | 92 | 84 | 91 |
| $I_3P_1N_2$ | 132 | 140 | 134 | 143 |
| $I_3P_1N_3$ | 170 | 178 | 182 | 191 |
| $I_3P_1N_4$ | 171 | 178 | 185 | 194 |
| $I_3P_2N_1$ | 91 | 98 | 90 | 97 |
| $I_3P_2N_2$ | 157 | 165 | 156 | 164 |
| $I_3P_2N_3$ | 201 | 210 | 204 | 213 |
| $I_3P_2N_4$ | 208 | 216 | 222 | 232 |
| $I_3P_3N_1$ | 96 | 102 | 94 | 101 |
| $I_3P_3N_2$ | 166 | 174 | 164 | 172 |
| $I_3P_3N_3$ | 216 | 225 | 218 | 227 |
| $I_3P_3N_4$ | 229 | 239 | 245 | 255 |
| **Mean** | **154** | **162** | **158** | **167** |
| **RMSE** | 8.65 | | 8.61 | |
| **CRM** | -5.53 | | -5.41 | |

M : Measured; S : Simulated

RMSE : Root mean square error; CRM : Coefficient of residual mass

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density (P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$; $N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$; $N_4$ = 300 Kg ha$^{-1}$

densities increased the drainage. The maximum and minimum drainage of 119.05 mm and 112.08 mm registered at $P_1$ x $N_3$ and $P_3$ x $N_I$ interactions respectively.

The interaction due to irrigation scheduling, plant density and nitrogen level differed for drainage. Irrigation scheduling at $I_1$ coupled with increase in plant density from $P_1$ to $P_3$ with increase in nitrogen level from $N_1$ to $N_4$ not shown variations in drainage, but at $I_2$ and $I_3$ irrigation scheduling increase in nitrogen level from $N_1$ to $N_3$ at $P_I$ plant density, and from $N_1$ to $N_4$ at $P_2$ and $P_3$ plant densities increased the drainage. Otherwise, the higher drainage loss of 212.13 mm recorded at $I_3$ x $P_1$ x $N_3$ interaction over others.

**4.3.3. 12 Simulated cumulative soil $NO_3$-nitrogen accumulation (kg $ha^{-l}$) (cf. Table 53)**

The soil $NO_3$ nitrogen accumulation at physiological maturity simulated from DSSAT v. 3.5 CERES maize model differed due to individual and interaction effect of irrigation scheduling, plant density and nitrogen level during both the years. The trend was similar over two seasons.

The increase in irrigation scheduling from $I_1$ to $I_3$ reduced the $NO_3$ nitrogen accumulation in the soil. The higher (52.89 kg $ha^{-l}$) and lower (28.31 kg $ha^{-l}$) $NO_3$ nitrogen accumulation recorded at $I_1$ and $I_3$ irrigation scheduling respectively.

The increase in plant density from $P_I$ to $P_3$ decreased the $NO_3$ nitrogen accumulation in the soil. At very high plant density ($P_3$) a minimum of 32.06 kg $ha^{-l}$ and at normal plant density ($P_1$) a maximum of 43.92 kg $ha^{-l}$ $NO_3$ nitrogen accumulation was registered.

The $NO_3$ nitrogen accumulation in soil at physiological maturity increased from 9.11 kg $ha^{-l}$ to 98.63 kg $ha^{-l}$ with increase in nitrogen from $N_1$ to $N_4$ respectively, the increase from $N_1$ (9.11 kg $ha^{-l}$) to $N_2$ (9.35 kg $ha^{-l}$) was very meager, however from $N_I$ to $N_3$ (32.43 kg $ha^{-l}$) was nearly three and half times and from $N_I$ to $N_4$ (98.63 kg $ha^{-l}$) nearly ten times higher.

The increase in irrigation scheduling from $I_1$ to $I_3$ coupled with increase in plant density from $P_1$ to $P_3$ drastically reduced the $NO_3$ nitrogen accumulation, the reduction from $I_1$ x $P_1$ (55.19 kg $ha^{-l}$) to $I_3$ x $P_3$ (21.80 kg $ha^{-l}$) interactions was nearly more than two times.

The interaction effect differed due to irrigation scheduling and nitrogen level for $NO_3$ nitrogen accumulation. The lower (8.53 kg $ha^{-l}$) and higher (135.27 kg $ha^{-l}$) $NO_3$ nitrogen accumulation were recorded at $I_1$ x $N_1$ and $I_1$ X $N_4$ interaction effects respectively.

The plant density and nitrogen level interaction effect differed for $NO_3$ nitrogen accumulation. The interaction $P_3$ x $N_1$ recorded lower (8.82 kg $ha^{-l}$) whereas $P_1$ x $N_4$ registered higher (114.53 kg $ha^{-l}$) $NO_3$ nitrogen accumulation in soil.

The $NO_3$ nitrogen accumulation in soil at physiological maturity differed due to interaction of irrigation scheduling, plant density and nitrogen level, and recorded maximum at $I_1$ x $P_1$ X $N_4$ (138.99 kg $ha^{-l}$) and minimum at $I_1$ x $P_3$ X $N_I$ (8.31 kg $ha^{-l}$) as compared to other interactions.

**4.3.3.13 Simulated cumulative $NO_3$-leaching (kg $ha^{-1}$) (cf. Table 54)**

The irrigation scheduling, plant density and nitrogen level differed in simulated cumulative $NO_3$ leaching.

The cumulative $NO_3$-leaching increased with increase in irrigation scheduling from $I_1$ to $I_3$, recorded a minimum of 0.95 kg $ha^{-l}$ at $I_1$, and a maximum of 5.34 kg $ha^{-l}$ at $I_3$.

Increase in plant density from $P_1$ to $P_3$ reduced the cumulative $NO_3$ leaching and recorded lower at $P_3$ (2.51 kg $ha^{-l}$) and higher at $P_1$ (2.78 kg $ha^{-1}$) plant densities.

The nitrogen application from $N_1$ to $N_4$ documented increase in $NO_3$ leaching from 2.48 kg $ha^{-l}$ at $N_I$ to 2.82 kg $ha^{-l}$ at $N_4$ nitrogen levels.

Increase in plant density from $P_I$ to $P_3$ at $1_2$ and $1_3$ accounted decreased $NO_3$ leaching, but at $I_1$ the increase in plant density recorded same cumulative $NO_3$ leaching. The lower value of 0.95 kg $ha^{-l}$ was recorded with $I_1$x $P_1$, $I_1$ X $P_2$ and $I_1$ x $P_3$ interactions, whereas a higher value of 5.68 kg $ha^{-l}$ recorded at $I_3$ x $P_1$ interactions as compared to others.

The cumulative $NO_3$ leaching increased with increase in irrigation scheduling from $I_2$ to $I_3$ coupled with increase in nitrogen application from $N_I$ to $N_4$ except at $I_1$, where in increase

**Table 52. Simulated drainage loss of water (mm) in maize as influenced by irrigation scheduling, plant density and nitrogen levels**

| Year | 1998-99 | | | | 1999-2000 | | | | Pooled | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** |
| **$I_1N_1$** | 63.99 | 63.99 | 63.99 | **63.99** | 48.49 | 48.49 | 48.49 | **48.49** | 56.24 | 56.24 | 56.24 | **56.24** |
| **$I_1N_2$** | 63.99 | 63.99 | 63.99 | **63.99** | 48.49 | 48.49 | 48.49 | **48.49** | 56.24 | 56.24 | 56.24 | **56.24** |
| **$I_1N_3$** | 63.99 | 63.99 | 63.99 | **63.99** | 48.49 | 48.49 | 48.49 | **48.49** | 56.24 | 56.24 | 56.24 | **56.24** |
| **$I_1N_4$** | 63.99 | 63.99 | 63.99 | **63.99** | 48.49 | 48.49 | 48.49 | **48.49** | 56.24 | 56.24 | 56.24 | **56.24** |
| **Mean** | **63.99** | **63.99** | **63.99** | **63.99** | **48.49** | **48.49** | **48.49** | **48.49** | **56.24** | **56.24** | **56.24** | **56.24** |
| **$I_2N_1$** | 109.52 | 102.67 | 100.38 | **104.19** | 66.28 | 60.07 | 58.29 | **61.55** | 87.90 | 81.37 | 79.34 | **82.87** |
| **$I_2N_2$** | 109.82 | 102.70 | 100.32 | **104.28** | 66.32 | 60.19 | 58.66 | **61.72** | 88.07 | 81.45 | 79.49 | **83.00** |
| **$I_2N_3$** | 110.81 | 103.22 | 100.51 | **104.85** | 66.72 | 60.22 | 58.83 | **61.92** | 88.77 | 81.72 | 79.67 | **83.39** |
| **$I_2N_4$** | 110.75 | 103.35 | 101.33 | **105.14** | 66.61 | 60.24 | 28.70 | **51.85** | 88.68 | 81.80 | 80.02 | **83.50** |
| **Mean** | **110.23** | **102.99** | **100.64** | **104.62** | **66.48** | **60.18** | **51.12** | **59.26** | **88.36** | **81.59** | **79.63** | **83.19** |
| **$I_3N_1$** | 233.81 | 227.66 | 223.03 | **228.17** | 188.48 | 182.18 | 178.29 | **182.98** | 211.15 | 204.92 | 200.66 | **205.58** |
| **$I_3N_2$** | 233.82 | 227.82 | 223.17 | **228.27** | 188.80 | 183.09 | 179.81 | **183.90** | 211.31 | 205.46 | 201.49 | **206.09** |
| **$I_3N_3$** | 234.55 | 228.18 | 223.44 | **228.72** | 189.71 | 183.60 | 180.00 | **184.44** | 212.13 | 205.89 | 201.72 | **206.58** |
| **$I_3N_4$** | 234.43 | 228.53 | 224.04 | **229.00** | 189.70 | 184.04 | 180.92 | **184.89** | 212.07 | 206.29 | 202.48 | **206.95** |
| **Mean** | **234.15** | **228.05** | **223.42** | **228.54** | **189.17** | **183.23** | **179.76** | **184.05** | **211.67** | **205.64** | **201.59** | **206.30** |
| **P X N Interaction** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** |
| **N1** | 135.78 | 131.44 | 129.13 | **132.12** | 101.08 | 96.91 | 95.02 | **97.67** | 118.43 | 114.15 | 112.08 | **114.89** |
| **N2** | 135.88 | 131.50 | 129.16 | **132.18** | 101.20 | 97.26 | 95.65 | **98.04** | 118.54 | 114.38 | 112.45 | **115.10** |
| **N3** | 136.45 | 131.80 | 129.31 | **132.52** | 101.64 | 97.44 | 95.77 | **98.28** | 119.05 | 114.62 | 112.54 | **115.40** |
| **N4** | 136.39 | 131.98 | 129.79 | **132.72** | 101.60 | 97.59 | 96.04 | **98.41** | 119.00 | 114.77 | 112.91 | **115.56** |
| **Mean** | **136.13** | **131.68** | **129.35** | **132.38** | **101.38** | **97.30** | **95.62** | **98.10** | **118.76** | **114.48** | **112.48** | **115.24** |

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density (P) : $P_1$ = 55555 Plants $ha^{-1}$; $P_2$ = 83333 Plants $ha^{-1}$; $P_3$ = 111111 Plants $ha^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg $ha^{-1}$; $N_2$ = 150 Kg $ha^{-1}$; $N_3$ = 225 Kg $ha^{-1}$; $N_4$ = 300 Kg $ha^{-1}$

**Table 53. Simulated cumulative Soil $NO_3$ nitrogen accumulation (kg $ha^{-1}$) accumulation at physiological maturity of maize as influenced by irrigation scheduling, plant density and nitrogen levels**

| Year | 1998-99 | | | | 1999-2000 | | | | Pooled | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** |
| **$I_1N_1$** | 8.80 | 8.46 | 8.34 | **8.53** | 8.82 | 8.47 | 8.27 | **8.52** | 8.81 | 8.47 | 8.31 | **8.53** |
| **$I_1N_2$** | 9.34 | 8.59 | 8.39 | **8.77** | 9.22 | 8.43 | 8.35 | **8.67** | 9.28 | 8.51 | 8.37 | **8.72** |
| **$I_1N_3$** | 64.11 | 61.59 | 57.23 | **60.98** | 63.27 | 59.35 | 48.58 | **57.07** | 63.69 | 60.47 | 52.91 | **59.02** |
| **$I_1N_4$** | 139.21 | 137.43 | 133.95 | **136.86** | 138.77 | 135.43 | 126.84 | **133.68** | 138.99 | 136.43 | 130.40 | **135.27** |
| **Mean** | **55.37** | **54.02** | **51.98** | **53.79** | **55.02** | **52.92** | **48.01** | **51.98** | **55.19** | **53.47** | **49.99** | **52.89** |
| **$I_2N_1$** | 10.03 | 9.52 | 9.29 | **9.61** | 9.70 | 9.34 | 9.05 | **9.36** | 9.87 | 9.43 | 9.17 | **9.49** |
| **$I_2N_2$** | 13.13 | 9.24 | 9.18 | **10.52** | 9.59 | 9.06 | 8.99 | **9.21** | 11.36 | 9.15 | 9.09 | **9.87** |
| **$I_2N_3$** | 39.92 | 17.77 | 13.70 | **23.80** | 24.30 | 13.53 | 10.68 | **16.17** | 32.11 | 15.65 | 12.19 | **19.98** |
| **$I_2N_4$** | 113.41 | 89.78 | 77.75 | **93.65** | 97.75 | 71.31 | 56.59 | **75.22** | 105.58 | 80.55 | 67.17 | **84.43** |
| **Mean** | **44.12** | **31.58** | **27.48** | **34.39** | **35.34** | **25.81** | **21.33** | **27.49** | **39.73** | **28.69** | **24.40** | **30.94** |
| **$I_3N_1$** | 9.70 | 9.15 | 8.91 | **9.25** | 9.75 | 9.27 | 9.03 | **9.35** | 9.73 | 9.21 | 8.97 | **9.30** |
| **$I_3N_2$** | 10.51 | 8.99 | 8.94 | **9.48** | 10.13 | 9.13 | 9.07 | **9.44** | 10.32 | 9.06 | 9.01 | **9.46** |
| **$I_3N_3$** | 34.66 | 16.30 | 12.46 | **21.14** | 22.05 | 13.40 | 10.75 | **15.40** | 28.36 | 14.85 | 11.61 | **18.27** |
| **$I_3N_4$** | 106.77 | 80.89 | 67.91 | **85.19** | 91.25 | 63.00 | 47.30 | **67.18** | 99.01 | 71.95 | 57.61 | **76.19** |
| **Mean** | **40.41** | **28.83** | **24.56** | **31.27** | **33.30** | **23.70** | **19.04** | **25.34** | **36.85** | **26.27** | **21.80** | **28.31** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 9.51 | 9.04 | 8.85 | **9.13** | 9.42 | 9.03 | 8.78 | **9.08** | 9.47 | 9.04 | 8.82 | **9.11** |
| **N2** | 10.99 | 8.94 | 8.84 | **9.59** | 9.65 | 8.87 | 8.80 | **9.11** | 10.32 | 8.91 | 8.82 | **9.35** |
| **N3** | 46.23 | 31.89 | 27.80 | **35.30** | 36.54 | 28.76 | 23.34 | **29.55** | 41.39 | 30.32 | 25.57 | **32.43** |
| **N4** | 119.80 | 102.70 | 93.20 | **105.23** | 109.26 | 89.91 | 76.91 | **92.03** | 114.53 | 96.31 | 85.06 | **98.63** |
| **Mean** | **46.63** | **38.14** | **34.67** | **39.82** | **41.22** | **34.14** | **29.46** | **34.94** | **43.92** | **36.14** | **32.06** | **37.38** |

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants $ha^{-1}$; $P_2$ = 83333 Plants $ha^{-1}$; $P_3$ = 111111 Plants $ha^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg $ha^{-1}$;$N_2$ = 150 Kg $ha^{-1}$; $N_3$ = 225 Kg $ha^{-1}$;$N_4$ = 300 Kg $ha^{-1}$

in nitrogen level from $N_l$ to $N_4$ recorded zero response. The minimum value of 0.95 kg $ha^{-l}$ at $I_1$ x $N_l$, $I_1$ X $N_2$, $I_1$ X $N_3$ and $I_1$ x $N_4$ and a maximum of 5.88 kg $ha^{-l}$ $NO_3$ leaching was recorded at $I_3$ x $N_4$ interactions.

Among the plant densities and nitrogen interactions, the lower at $P_3$ x $N_l$ (2.38 kg $ha^{-1}$) and higher at $P_1$ x $N_4$ (2.98 kg $ha^{-l}$) cumulative $NO_3$ leaching was registered.

The interaction of irrigation scheduling, plant density and nitrogen level differed. Irrigation scheduling at $I_1$ did not document any response for increased nitrogen coupled with increase in plant density. However, at $I_2$ and $I_3$ the cumulative $NO_3$ leaching reported similar and either reduced or increased trend, depending on treatment combinations. $NO_3$ leaching reduced with increase in plant density from $P_1$ to $P_3$ at each level of nitrogen or it increased with increase in nitrogen level from $N_1$ to $N_4$ at each level of plant density. The higher $NO_3$ leaching of 6.25 kg $ha^{-1}$ recorded at $I_3$ x $P_1$ X $N_4$ interaction as compared to other effects.

**Table 54. Simulated cummulative nitrate leaching (kg ha$^{-1}$) of maize as influenced by irrigation scheduling, plant density and nitrogen levels**

| Year | 1998-99 | | | | 1999-2000 | | | | Pooled | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** | **$P_1$** | **$P_2$** | **$P_3$** | **Mean** |
| **$I_1N_1$** | 1.10 | 1.10 | 1.10 | **1.10** | 0.80 | 0.80 | 0.80 | **0.80** | 0.95 | 0.95 | 0.95 | **0.95** |
| **$I_1N_2$** | 1.10 | 1.10 | 1.10 | **1.10** | 0.80 | 0.80 | 0.80 | **0.80** | 0.95 | 0.95 | 0.95 | **0.95** |
| **$I_1N_3$** | 1.10 | 1.10 | 1.10 | **1.10** | 0.80 | 0.80 | 0.80 | **0.80** | 0.95 | 0.95 | 0.95 | **0.95** |
| **$I_1N_4$** | 1.10 | 1.10 | 1.10 | **1.10** | 0.80 | 0.80 | 0.80 | **0.80** | 0.95 | 0.95 | 0.95 | **0.95** |
| **Mean** | **1.10** | **1.10** | **1.10** | **1.10** | **0.80** | **0.80** | **0.80** | **0.80** | **0.95** | **0.95** | **0.95** | **0.95** |
| **$I_2N_1$** | 2.20 | 2.10 | 2.00 | **2.10** | 1.20 | 1.10 | 1.00 | **1.10** | 1.70 | 1.60 | 1.50 | **1.60** |
| **$I_2N_2$** | 2.20 | 2.10 | 2.00 | **2.10** | 1.20 | 1.10 | 1.00 | **1.10** | 1.70 | 1.60 | 1.50 | **1.60** |
| **$I_2N_3$** | 2.30 | 2.10 | 2.00 | **2.13** | 1.20 | 1.10 | 1.00 | **1.10** | 1.75 | 1.60 | 1.50 | **1.62** |
| **$I_2N_4$** | 2.30 | 2.10 | 2.00 | **2.13** | 1.20 | 1.10 | 1.00 | **1.10** | 1.75 | 1.60 | 1.55 | **1.63** |
| **Mean** | **2.25** | **2.10** | **2.00** | **2.12** | **1.20** | **1.10** | **1.00** | **1.10** | **1.73** | **1.60** | **1.51** | **1.61** |
| **$I_3N_1$** | 5.80 | 5.50 | 5.30 | **5.53** | 4.40 | 4.20 | 4.10 | **4.23** | 5.10 | 4.85 | 4.70 | **4.88** |
| **$I_3N_2$** | 6.20 | 5.60 | 5.40 | **5.73** | 4.70 | 4.30 | 4.20 | **4.40** | 5.45 | 4.95 | 4.80 | **5.07** |
| **$I_3N_3$** | 6.80 | 6.30 | 5.90 | **6.33** | 5.00 | 4.70 | 4.50 | **4.73** | 5.90 | 5.50 | 5.20 | **5.53** |
| **$I_3N_4$** | 7.30 | 6.80 | 6.40 | **6.83** | 5.20 | 4.90 | 4.70 | **4.93** | 6.25 | 5.85 | 5.55 | **5.88** |
| **Mean** | **6.53** | **6.05** | **5.75** | **6.11** | **4.83** | **4.53** | **4.38** | **4.58** | **5.68** | **5.29** | **5.06** | **5.34** |
| **NXP Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 3.03 | 2.90 | 2.80 | **2.91** | 2.13 | 2.03 | 1.97 | **2.04** | 2.58 | 2.47 | 2.38 | **2.48** |
| **N2** | 3.17 | 2.93 | 2.83 | **2.98** | 2.23 | 2.07 | 2.00 | **2.10** | 2.70 | 2.50 | 2.42 | **2.54** |
| **N3** | 3.40 | 3.17 | 3.00 | **3.19** | 2.33 | 2.20 | 2.10 | **2.21** | 2.87 | 2.68 | 2.55 | **2.70** |
| **N4** | 3.57 | 3.33 | 3.17 | **3.36** | 2.40 | 2.27 | 2.17 | **2.28** | 2.98 | 2.80 | 2.68 | **2.82** |
| **Mean** | **3.29** | **3.08** | **2.95** | **3.11** | **2.28** | **2.14** | **2.06** | **2.16** | **2.78** | **2.61** | **2.51** | **2.63** |

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$

Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$;$N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$;$N_4$ = 300 Kg ha$^{-1}$

# V. DISCUSSION

Efforts were made to exploit the production potential of maize during winter season through agronomic investigations under irrigated condition. Further, it was felt necessary to asses the capabilities of process based simulation model DSSAT v 3.5 CERES maize for predicting the growth and yield of maize. The objectives of the study were (i) to know the performance of maize varieties to different planting dates during winter season. (ii) To study the effect of irrigation scheduling, plant density and nitrogen levels to maximise yield of winter maize. (iii) To generate the genetic coefficients of maize varieties for running the DSSAT v 3.5 CERES-maize model (iv) To evaluate the DSSAT v 3.5 CERES maize model for simulating growth and yield of maize varieties as influenced by planting dates and compare with the field data, and (v) To examine the performance of DSSAT v 3.5 CERES maize model for simulating the effect of irrigation scheduling, plant density and nitrogen levels on growth and yield of maize and to compare with measured data to know the accuracy and tendency of the model predictions. The results of the field investigations and simulation studies are discussed in this chapter.

## 5.1 WEATHER AND CROP PERFORMANCE

The meterological data (Appendix-1 and Fig.1 and 2) revealed that the seasonal conditions during the crop growth periods were normal. The mean maximum and minimum temperature, solar radiation and relative humidity during 1998-99 and 1999-2000 cropping seasons did not deviate much from the average of the past 35 years, the condition was well suited for cultivation of maize. With all that, 1999-2000 season was extremely better with respect to maximum and minimum temperature, and solar radiation which were optimum for maize, hence, reflected well in grain yield. In addition, there were no severe incidence of pests and diseases except negligible incidence of cutworms during seedling stages and minor incidence of cob borer at later stages of crop growth in planting dates and varietal experiment during 1998-99 *rabi* season.

## 5.2 EFFECT OF PLANTING DATES ON GROWTH AND YIELD OF MAIZE VAREITIES

The grain yield obtained was generally higher in the present investigations and attributed to suitable climatic conditions prevailed during the cropping season, besides better dosage of nutrients and supply of required water as these are the primary growth factors which might have led to higher yield. This was in accordance with the yield reported by Setty (1981) and Gollar (1996) under similar situations. The productivity was better during 1999-2000 season due to optimum climatic condition, specially the maximum and minimum temperature, and solar radiation.

### 5.2.1 Performance of varieties

Maize varieties differed significantly with respect to grain yield (Fig. 5). Among the varieties, DMH-2 produced significantly higher grain yield (8191 kg ha$^{-1}$) of 9, 23, 30 and 122 per cent higher than DMH-1, Deccan-103, Prabha (G-57), and Renuka (G-25) respectively. The varietal difference in grain yield is confirmed with the results of Krishnamurthy *et al*. (1972); Halemani *et al*. (1980a); Setty (1981); Gollar (1996) and Anon (2000). The higher grain yield of DMH-2 was attributed to the higher growth and yield contributing characters (Setty, 1981; Gollar, 1996; and Anon, 2000), specially the LAI, total dry matter production, cob dry matter production, grain weight, grain ear$^{-1}$ and grain number m$^{-2}$.

The yield potential of any genotype lies in its ability to produce more number of grains cob$^{-1}$ and higher grain weight (g grain$^{-1}$). Higher seed number generally is the component of yield associated with yield improvement (Singh, 1966; Pande *et al*., 1971). The higher grain weight and number of grains cob$^{-1}$ are mainly associated with higher grain yield (Krishnamurthy *et al*., 1974; Krishnamurthy *et al*., 1973b; Halemani *et al*., 1980a; Halemani *et al*., 1980b; Setty, 1981; Gollar, 1996).

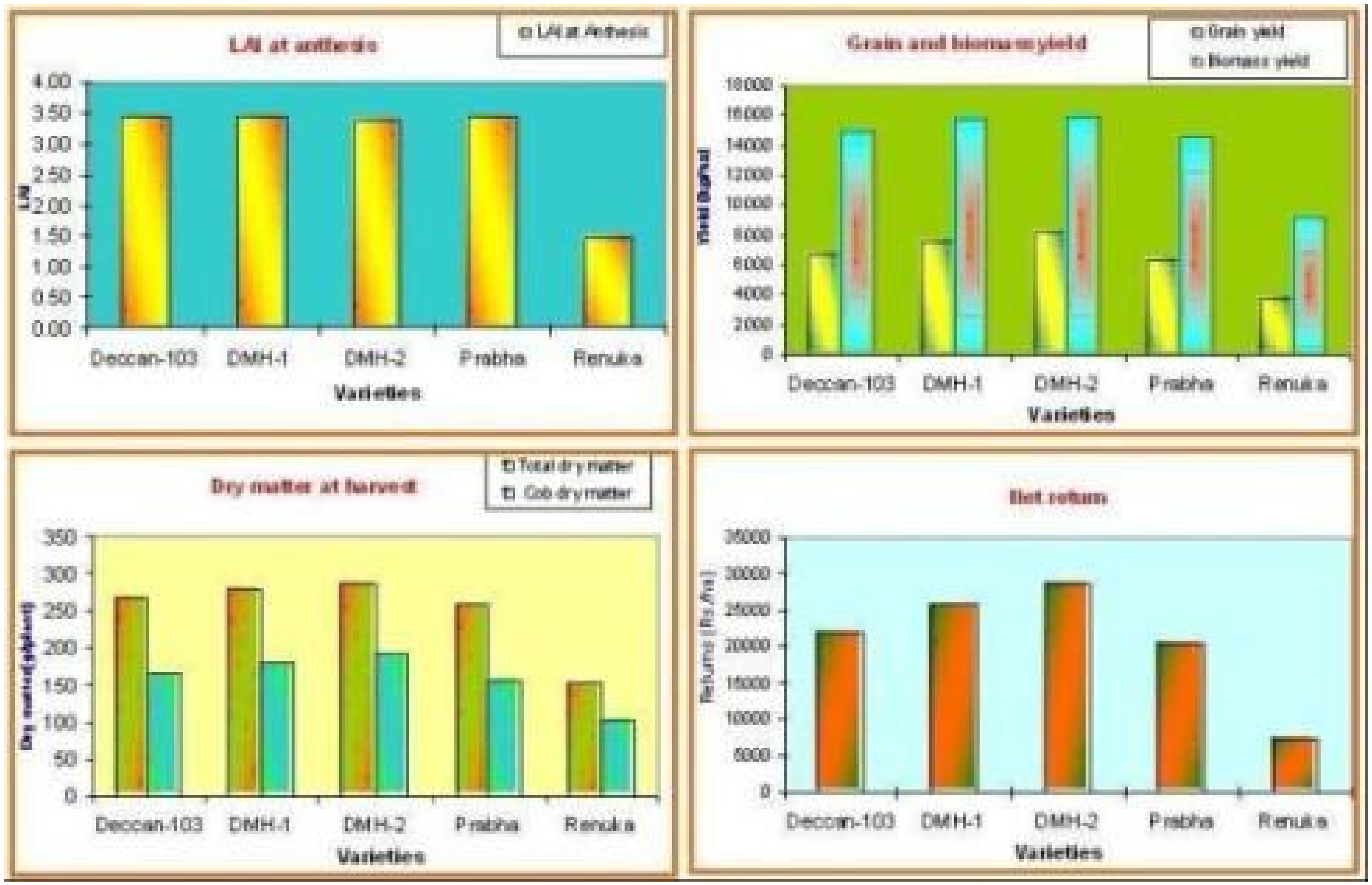



**Fig 5. LAI at anthesis, cob dry matter, TDM, grain and biomass yield and net return of maize varieties**

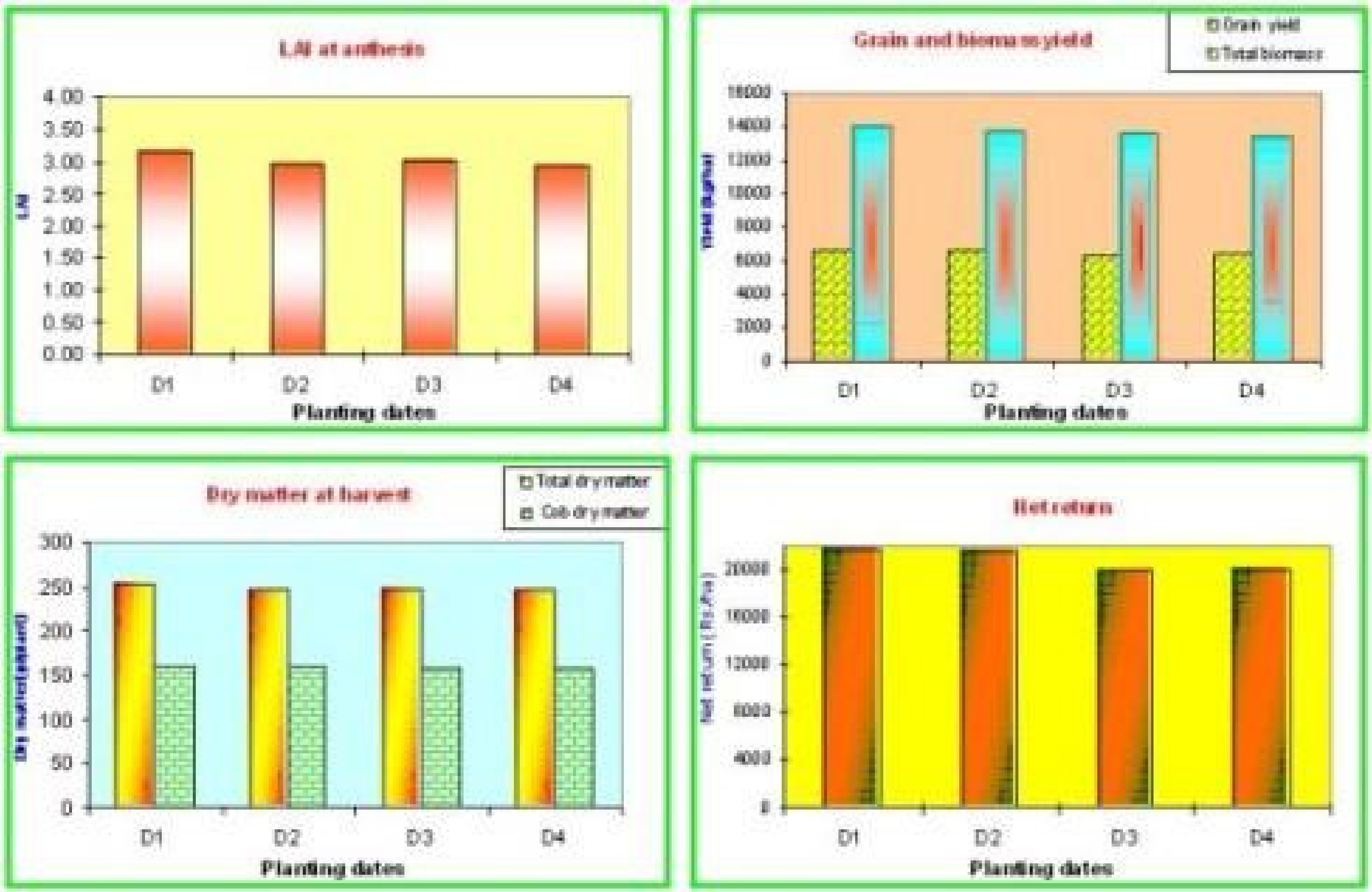



**Fig 6. Number of leaves of maize varieties at different growth stages as influenced by planting dates.**

Significantly higher total dry matter accumulation of DMH-2 (287.46 g plant$^{-1}$) lead to better partitioning of dry matter (191.57 g plant$^{-1}$) to cob, inturn higher grain number m$^{-2}$ (2579 grains resulted in higher grain yield. The higher dry matter plant$^{-1}$ might have contributed to achieve higher biomass (15801 kg ha$^{-1}$) at physiological maturity as compared to other varieties. Similarly the partitioning of dry matter to grain in case of DMH-2 is higher as evident from the higher harvest index (0.518). In addition, higher grain weight recorded in DMH-2 (318 mg grain$^{-1}$) is attributed to more number of days taken from anthesis to physiological maturity namely longer grain filling period might have helped in better partitioning and accumulation of dry matter to grain (Setty, 1981). Further, better resources utilization of DMH-2 as evident by water use (551.84 mm) resulted in better growth and yield attributes, inturn higher grain yield and water use efficiency. In addition, because of substantial improvement in grain yield, DMH-2 recorded higher net return of Rs.28,830 ha$^{-1}$ (Fig.5) and benefit cost ratio of 3.00.

### 5.2.2 Effect of planting dates

The difference in grain yield due to planting date was significant (Fig.6). Grain yield produced in October I fortnight (6653 kg ha$^{-1}$) and October II fortnight (6630 kg ha$^{-1}$) planting dates was significantly higher than November I fortnight (6285 kg ha$^{-1}$) and November II fortnight (6319 kg ha$^{-1}$). The higher grain yield of 5.9 and 5.3 per cent in October I fortnight and 5.1 and 4.6 per cent in October II fortnight compared to late planting dates was attributed to higher value of growth and yield components. Similar results were recorded by several workers (Setty, 1981; Anon, 1994; Anon., 1997, Anon, 1998 and Anon., 2000).

The higher leaf area index recorded in October I and October II fortnight planting dates (0.78, 3.16 and 1.25 and 0.72, 2.94 and 1.20 at 30 DAS, anthesis and physiological maturity respectively) might have resulted in better radiation use efficiency and higher synthesis of metabolites leading to higher total dry matter production (253.49 and 246.71 g plant$^{-1}$ at physiological maturity) and inturn higher grain yield. The dry matter partitioning to cob at physiological maturity is higher (161.26 and 160.24 g plant$^{-1}$) and this might have lead to achieve better yield. The grain weight (g grain$^{-1}$) significantly decreased with every fortnight delay in planting dates from October I fortnight to November II fortnight. This was mainly because of reduced grain filling period in later planting dates due to increase in temperature or in other words cooler climate prevailed during grain filling period in early planting dates and prolonged grain filling period might have lead to accumulation of higher translocates to seeds, inturn higher grain weight. The results are in conformity with the findings of Hunter *et al*., (1977); Setty, (1981); Badu-Apraku *et al*., (1983) and Rajireddy, (1991).

In addition, though there was decrease in grains ear$^{-1}$ and grain number m$^{-2}$ at early planting dates such as October I and II fortnight, the significant increase in grain weight resulted in higher grain yield. Similar observations were recorded by Setty (1981) who attributed that temperature and solar radiation prevailed during anthesis to grain formation stage influenced to great extent.

Further, lesser water use with October I and II fortnight planting dates (473.71 and 496.92 mm respectively) over others was attributed to cooler climate with low evaporation during the growth periods.

Added to this, because of higher grain yield, October I and II fortnight planting dates recorded higher net return (Fig. 6) of Rs.21678 and 21480 ha$^{-1}$ and, B:C ratio of 2.55 and 2.53 respectively.

### 5.2.3 Interaction of varieties and planting dates

The interaction of varieties and planting dates differed significantly (Fig. 7). DMH-2 produced significantly higher grain yield at all the planting dates. Significantly higher grain yield was obtained by DMH-2 planted in October II fortnight (8553 kg ha$^{-1}$) followed by DMH-2 with October I fortnight planting (8255 kg ha$^{-1}$) as compared to other interactions.

The differential response of the varieties to planting dates can be related to their differential response of growth and yield contributing characters (Krishnamurthy, *et al*., 1973a; Muleba and Hart, 1983; Muleba *et al*., 1983, Manishkumar, 1998; Anon, 2000; Norwood, 2001).

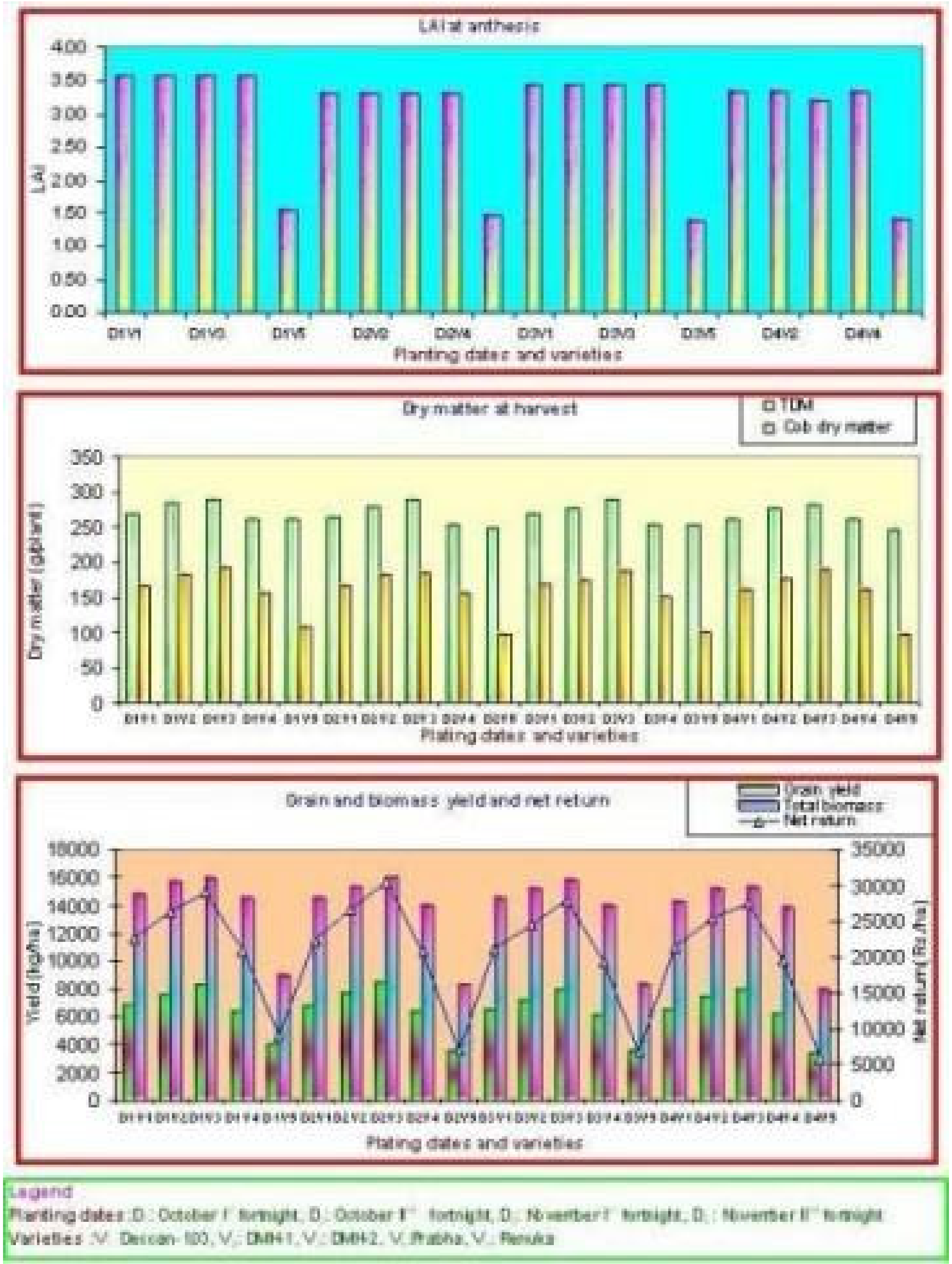



**Fig 7. LAI at anthesis, cob dry matter, TDM, grain and biomass yield at harvest and net return of maize varieties as influenced by planting dates**

The interaction of varieties and planting dates were significant with respect to biomass, dry matter production and its accumulation in cob, harvest index, grain weight, grains ear$^{-1}$ and grain number m$^{-2}$. The greater response of DMH-2 to planting dates with respect to grain yield as compared to DMH-1 and Deccan-103 hybrids, and prabha (G-52) and Renuka (G-25) composites was due to higher biomass production and its partitioning to cob in hybrids compared to composites.

The increase in biomass of DMH-2 with October II fortnight and October I fortnight planting was ascribed to significantly higher leaf area index that resulted in better radiation use efficiency and synthesis of metabolites which lead to higher total dry matter production (289.29 and 288.96 g plant$^{-1}$ respectively) and its partitioning to cob (195.98 and 192.33 g plant$^{-1}$) and ultimately higher grain yield. Further, these treatment combinations recorded optimum use of water (548.91 and 517.78 mm respectively) by recording higher grain yield, resulting in higher water use efficiency (15.58 and 15.94 kg ha$^{-1}$ mm$^{-1}$ respectively). Besides, these treatment combinations also recorded higher net return (Fig. 7) of Rs.30,464 ha$^{-1}$ and Rs. 29,145 ha$^{-1}$ respectively because of higher grain yield.

## 5.3 EFFECT OF IRRIGATION SCHEDULING, PLANT DENSITY AND NITROGEN LEVELS ON GROWTH AND YIELD OF WINTER MAIZE

The growth and yield of winter maize were significantly influenced by irrigation scheduling, plant densities and nitrogen levels (Verma and Singh, 1976; Setty, 1981; Prasad *et al.*, 1987; Roy and Tripathi, 1987; Sridhar and Singh, 1989; Shridhar *et al.*, 1991a; Singh *et al.*, 1997 and Manishkumar, 1998).

### 5.3.1 Response of winter maize to irrigation scheduling based on IW:CPE ratio

Significantly higher grain yield (Fig.8 and plate 2) was recorded at irrigation with 0.9 IW:CPE ratio (7692 kg ha$^{-1}$) as compared to 0.6 IW:CPE ratio (6383 kg ha$^{-1}$). The yield obtained at 0.9 IW : CPE ratio was on par with 1.2 IW:CPE ratio (7664 kg ha$^{-1}$). The results are in accordance with the grain yield obtained by Shridhar *et al.* (1991a); Bandyopadhyay and Mallick (1996), and Singh *et al.* (1997). The higher yield produced at $I_2$ is attributed to increase in LAI, dry matter production and its distribution to cob, biomass, harvest index, grain weight, grains ear$^{-1}$ and grain number m$^{-2}$.

Irrigation scheduling at $I_2$ recorded significantly higher LAI (3.88, 3.79, 2.52 and 1.83 at 60, 90, 120 DAS and at physiological maturity respectively), total dry matter of 230.56 g plant$^{-1}$ at physiological maturity and its distribution to leaf (36.57 g plant$^{-1}$), stem (52.64 g plant$^{-1}$), cob (141.34 g plant$^{-1}$) resulting in higher total biomass 17811 kg ha$^{-1}$). The dry matter partitioning to cob might have lead to record higher grain weight (228 mg grain$^{-1}$) and grains ear$^{-1}$ (350 grains). The harvest index is one of the indices used to evaluate partitioning efficiency. In $I_2$ higher harvest index of 0.436 was recorded over $I_3$ (0.424) due to better partitioning to cob which resulted higher grain yield.

The differential response of maize to irrigation scheduling can be related to their differential response in grain yield contributing characters. Significantly higher grain weight, grains ear$^{-1}$ and grain number m$^{-2}$ (2788 grains) were recorded at $I_2$ than $I_1$ and $I_3$ resulting in higher grain yield. The results are in conformity with the findings of many workers (Roy and Tripathi, 1987; Shridhar *et al.* 1991a; Bandyopadhyay and Mallick, 1996).

Increase in irrigation from 0.6 to 1.2 IW:CPE ratio increased the water use because of increase in frequency and number of irrigations and resulted in continuous availability of water. However, grain yield did not proportionately increased but, plateaud at $I_2$, which recorded higher water use efficiency (16.09 kg ha$^{-1}$ mm$^{-1}$). Similar results were obtained by Bandyopadhyay and Mallick (1996).

Irrigation at 0.9 IW:CPE ratio registered higher nitrogen uptake (163 kg ha$^{-1}$) which is attributed to higher total biomass yield as a result of good moisture availability at root zone. In addition, applied nitrogen was used relatively better as indicated by $NO_3$ nitrogen accumulation at harvest, the higher $NO_3$ nitrogen accumulation at $I_1$ is attributed to lack of moisture resulting in lower utilization of applied nitrogen. Further, increase in irrigation level

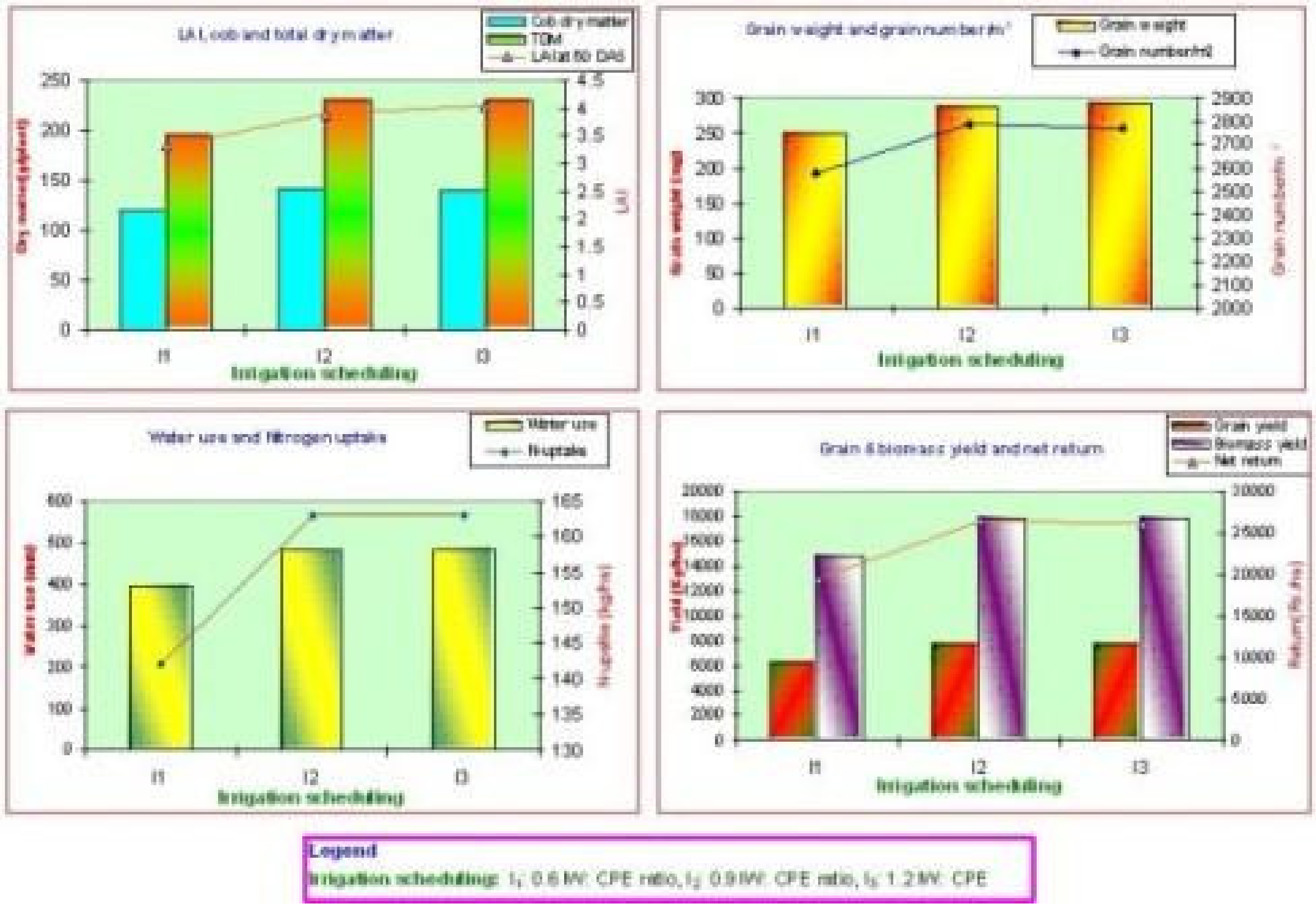



**Fig 8. Effect of irrigation scheduling on growth, yield, water use, nitrogen uptake and net return of maize**

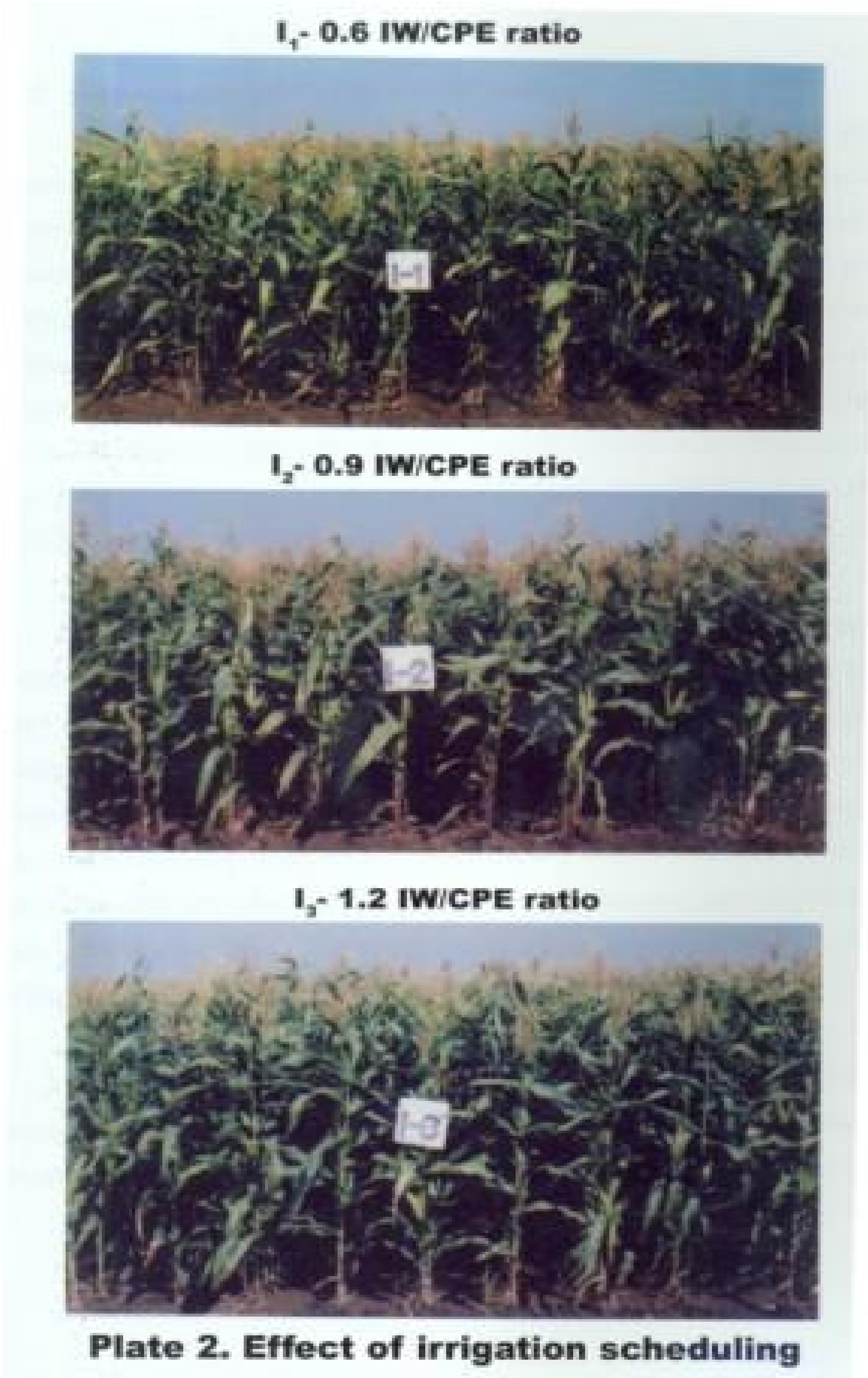



Plate 2. Effect of irrigation scheduling

increased the drainage which resulted in loss of nitrogen through $NO_3$ leaching. Irrigation at $I_2$ besides maximizing the grain yield, effectively used applied water (477.37 mm) and nitrogen (163 kg N uptake $ha^{-1}$) and minimized the drainage loss of water (83.19 mm) and $NO_3$ leaching (1.61 kg $ha^{-1}$).

Irrigation at IW:CPE ratio of 0.9 also recorded higher net return (Fig.8) of Rs.26,472 $ha^{-1}$ and B:C ratio of 2.75 because of higher grain yield.

### 5.3.2 Response of winter maize to plant density

The growth and yield of maize significantly influenced by plant density due to differential availability of resources like light, moisture and nutrients. Under irrigated condition, increase in plant density from $P_1$ (normal 55555 plants $ha^{-1}$) to $P_3$ (very high 111111 plants $ha^{-1}$) increased grain yield (Fig. 9 and plate 3) from 6941 kg $ha^{-1}$ to 7373 kg $ha^{-1}$. The increase in grain yield at $P_3$ over $P_1$ was 5 per cent and that at $P_2$ over $P_1$ was 4.8 per cent. Higher grain yield at very high plant density ($P_3$) has been reported by many workers both from India and other countries (Termunde *et al*., 1963; Goydani and Singh, 1968; Sharma and Gupta, 1968; Setty, 1981; Reddy *et al*., 1987; Gollar, 1996).

The difference in grain yield under varying plant densities may be ascribed to the differences in yield attributes. The grain weight and grain ear$^{-1}$ increased with every step decrease in plant density from $P_3$ to $P_1$, while grain number $m^{-2}$ significantly increased with every step increase in plant density from $P_1$ to $P_3$. The better performance with respect to grain weight and grains ear$^{-1}$ due to decrease in plant density could be related to total dry matter production plant$^{-1}$ and its distribution to different parts especially to cob. Similar results were noticed by Krishnamurthy *et al.* (1973b), Setty (1981) and Gollar (1996).

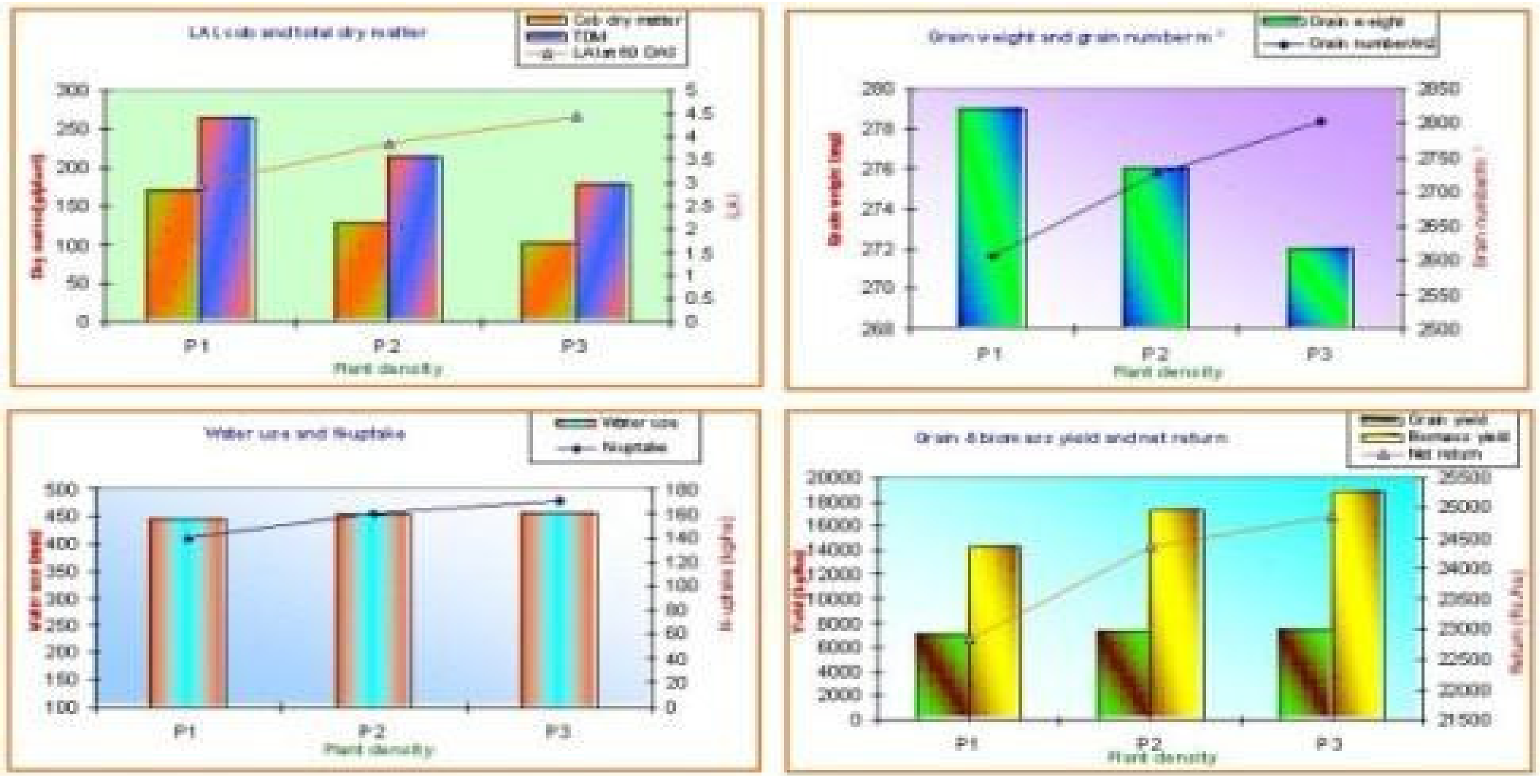
The grain yield $ha^{-1}$ increased significantly with increase in plant density from $P_1$ to $P_3$ is ascribed to significant increase in grain number $m^{-2}$ because of higher plant population per unit area at higher plant density.

Further, significantly lower grain weight and lower grains ear$^{-1}$ at higher plant density may be due to greater competition between plants for light, water and nutrients, which might have suppressed the performance of individual plants and thus produced lower number of grains ear$^{-1}$ and grain weight. Decreased yield components and increased yield at higher plant density have been reported by many investigations (Gupta, 1975; Tripathi, 1971; Nageswarareddy and Kaliappa, 1974; Setty, 1981; Gollar, 1996).

Increase in plant density from normal ($P_1$) to very high ($P_3$) significantly increased total biomass yield from 14291 to 18842 kg $ha^{-1}$ which was attributed to increase in plant height from 210.03 to 221.75 cm, higher LAI at all the growth periods resulted in better radiation use efficiency due to increased number of plants per unit area at higher plant density over normal plant density ($P_1$). Increase in plant density (from $P_1$ to $P_3$) resulted in decreased harvest index, and could be related to lower partitioning of dry matter into cobs or grains due to increased competition for available resources such as light, moisture and nutrients (Setty, 1981; Gollar, 1996).

Increase in plant density from $P_1$ to $P_3$ significantly increased the competition for available water, thus increasing the water use and decreasing the loss of water through drainage. Hence, significantly higher water use and lower drainage loss was registered at very high plant density besides higher grain yield and higher water use efficiency. The nitrogen uptake increase with increase in plant density from $P_1$ to $P_3$ may be related to increased number of plants per unit area which resulted in higher total biomass per unit area. In addition, the $NO_3$ nitrogen accumulation and cumulative $NO_3$ leaching reduced with increase in plant density, which clearly indicated that applied nutrients (specially the nitrogen) were effectively utilized.

Increase in plant density increased the grain yield at $P_3$ and recorded higher net return (Rs 24854 $ha^{-1}$). The higher net return at $P_3$ (Fig. 9) could be attributed to the fact that substantial increase in grain yield (5%) at $P_3$ over $P_1$.




Legend
Plant density: $P_1$ 55,555 plants $ha^{-1}$, $P_2$ 83,333 plants $ha^{-1}$, $P_3$ 111111 plants ha

**Fig 9. Effect of plant density on growth, yield, water use, nitrogen uptake and net return of maize**

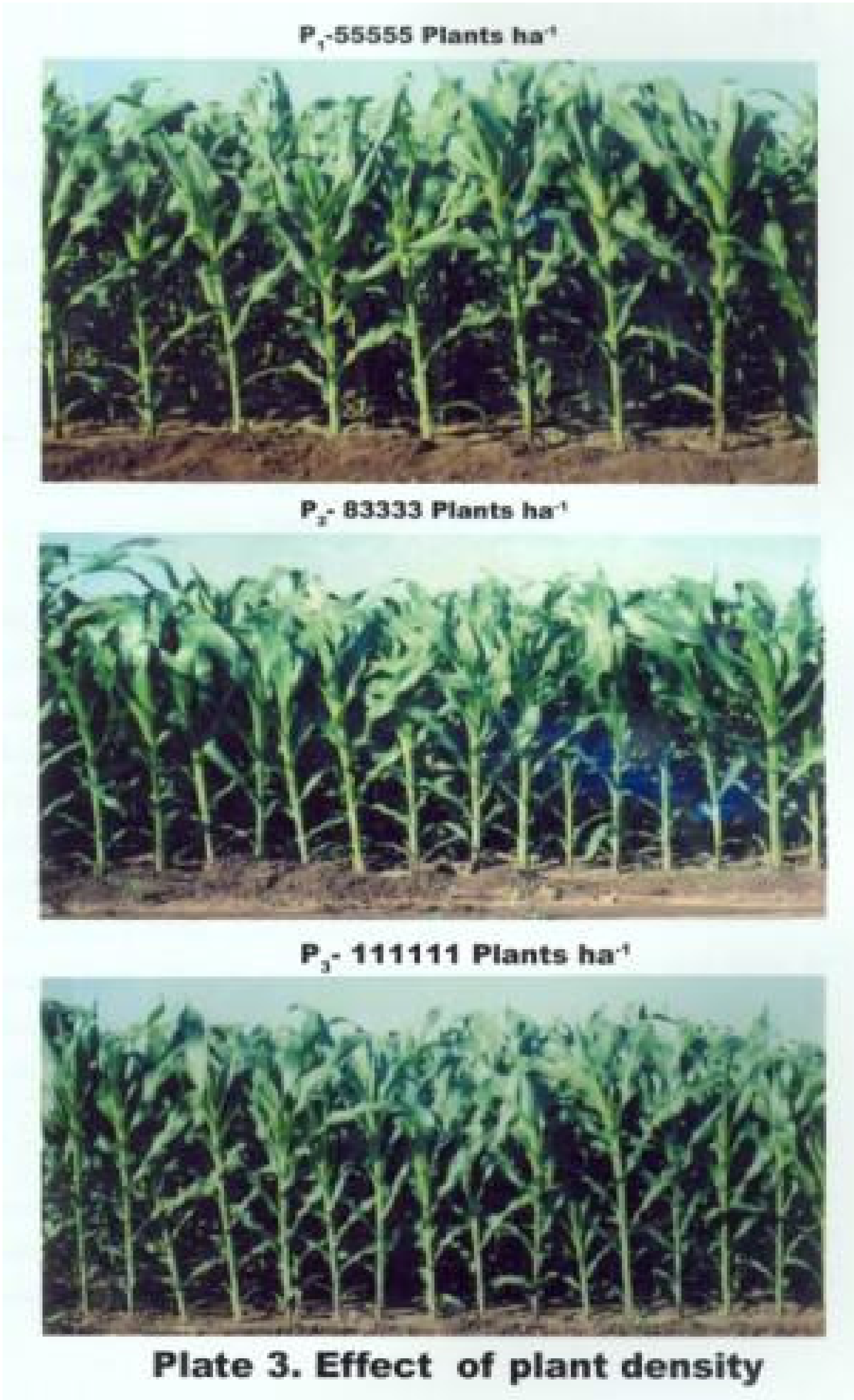



Plate 3. Effect of plant density

### 5.3.3 Response of winter maize to nitrogen

The grain yield (Fig.10) increased significantly with increase in nitrogen application from 50 per cent recommended level of 75 kg $ha^{-1}$ to 150 per cent recommended level of 225 kg $ha^{-1}$. The per cent increase in grain yield of maize at Nitrogen level 225 kg $ha^{-1}$ (7591 kg $ha^{-1}$) over 75 kg $ha^{-1}$ (6101 kg $ha^{-1}$) and 150 kg $ha^{-1}$ (7478 kg $ha^{-1}$) was 23.1 and 1.3 respectively. The grain yield of maize at 225 and 300 kg N $ha^{-1}$ (7586 kg $ha^{-1}$) were on par. The differential response to grain yield in relation to increased level of nitrogen are in conformity with the findings of Singh *et al* (1965); Krishnamurthy *et al* (1973b), Gupta (1975); Halemani *et. al* (1976); Halemani *et al* (1980a); Setty (1981); Nandal and Agarawal (1989); Bangarwa *et al* (1992); and Manishkumar (1998). The increase in grain yield due to increased level of nitrogen upto 150 per cent recommended dose (225 kg $ha^{-1}$) could be attributed to the favourable effect of nitrogen on yield components such as grain weight, grains $ear^{-1}$ and grain number $m^{-2}$.

Increase in nitrogen level from $N_1$ (75 kg $ha^{-1}$) to $N_3$ (225 kg $ha^{-1}$) increased the grain weight (272 to 278 mg $grain^{-1}$), grains $ear^{-1}$ (306 to 361 grains $ear^{-1}$) and grain number $m^{-2}$ (2297 to 2873 grains). These results are in conformity with the results of many investigations (Singh, 1967; Sharma, 1973; Sharma *et al*. 1979; Setty, 1981; Manishkumar, 1998). Increase in grains $ear^{-1}$ and grain number $m^{-2}$ was attributed to better LAI, which consequently increased the radiation use efficiency and resulted in the total dry matter production and its distribution to cobs as evidenced at 90 DAS. Sink size increased due to increased translocation of assimilates into cob. The results are in accordance with the findings of Krishnamurthy *et al*. (1973b) and Setty (1981). The higher total dry matter production lead to increase in total biomass at higher nitrogen level. The grain yield depends on the partitioning of dry matter into its economical portion and its conversion into grain (Donald, 1962). The above ground total biomass and harvest index were significantly higher at higher level of nitrogen. This was ascribed to larger proportion of total dry matter and its conversion into grain.

The higher grain yield of maize was also attributed to increased level of nitrogen uptake by the crop, with further increase in nitrogen at $N_4$ though the grain yield was on par with $N_3$, it increased the $NO_3$ nitrogen accumulation and $NO_3$ leaching, mainly due to application of nitrogen more than the required quantity.

The net return (Fig. 10) of Rs.25733 $ha^{-1}$ obtained at $N_3$ compared to other levels of nitrogen is attributed to higher grain yield. However, the net return and B:C ratio did not differ from $N_2$ and $N_3$ which were mainly due to additional cost incurred for additional 75 kg N $ha^{-1}$ in $N_3$ over $N_2$ nitrogen level.

### 5.2.4 Interaction effect of irrigation and plant density

Increase in irrigation level from 0.6 ($I_1$) to 0.9 ($I_2$) IW:CPE ratio combined with increase in plant density from $P_1$ (55555 plants $ha^{-1}$) to $P_3$ (111111 plants $ha^{-1}$) significantly increased the grain yield of maize (Fig.11). The interaction effect on grain yield due to irrigation was greater at higher plant density than at lower plant density. Significantly higher yield obtained at $I_2$ X $P_3$ (7933 kg $ha^{-1}$) compared to other treatment combinations is attributed to better growth and yield parameters such as LAI, grain weight, grains $ear^{-1}$ and grain number $m^{-2}$.

The increase in biomass with increase in irrigation was greater at higher plant density than at normal plant density. The total dry matter production (g $plant^{-1}$) at harvest differed significantly due to interaction of irrigation scheduling and plant densities. The decrease in total dry matter production $plant^{-1}$ with increase in plant densities was greater with increasing level of irrigation. This was more compensated by greater number of plants per unit area at high plant densities and might have resulted in higher biomass and inturn higher grain yield at $I_3$ x $P_3$ interaction. The results confirm the findings of Reddy *et al*. (1987); Singh *et al*. (1997). Though $I_2$ x $P_3$, recorded relatively less water use as compared to $I_3$ x $P_3$ and $I_3$ x $P_2$, however because of higher yield, it recorded comparable WUE. In addition, this treatment combination recorded higher nitrogen uptake (kg $ha^{-1}$) and $NO_3$ accumulation at physiological maturity, but comparable drainage water loss and negligible $NO_3$ leaching. This was attributed to better utilization of available water and nutrients. The higher grain yield at $I_2$ x $P_3$ interaction lead to higher net return and on par B:C ratio with $I_2$ x $P_2$ and was higher over other interactions of I x P.

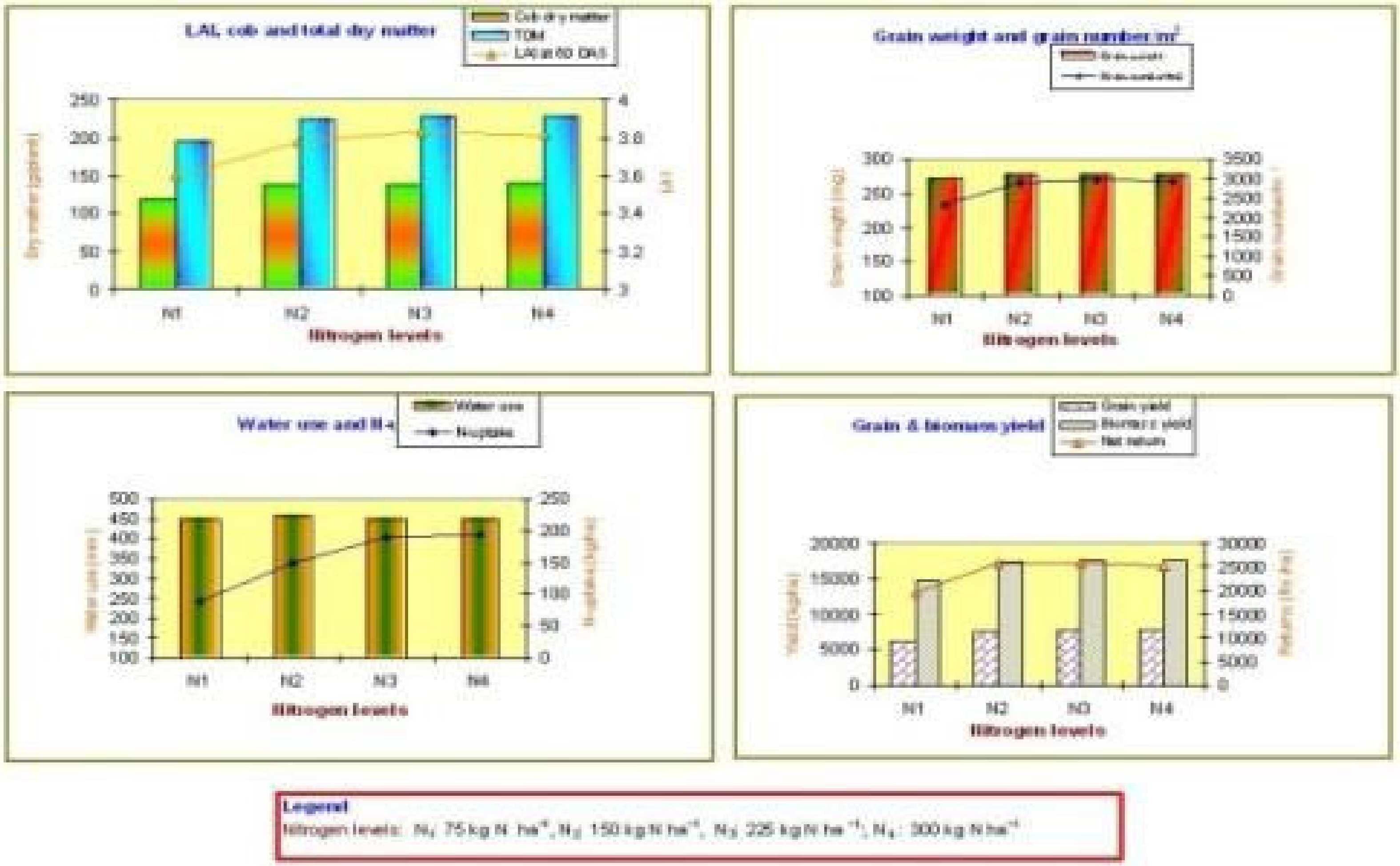



**Fig 10. Effect of nitrogen levels on growth, yield, water use, nitrogen uptake and net return of maize.**

### 5.3.4 Interaction effect of irrigation scheduling and nitrogen levels

The grain yield (Fig.12) due to interaction effect of irrigation scheduling and nitrogen level differed significantly. The increase in irrigation level from $I_1$ (0.6 IW:CPE ratio) to $I_2$ (0.9 IW:CPE ratio) and nitrogen level from $N_1$ (75 kg ha$^{-1}$) to $N_3$ (225 kg ha$^{-1}$) increased the grain yield. Further, increase in irrigation scheduling from $I_2$ to $I_3$ (1.2 IW:CPE ratio) and nitrogen level form $N_3$ (225 kg ha$^{-1}$) to $N_4$ (300 kg ha$^{-1}$) did not increase the grain yield. The combination of $I_3$ x $N_4$ recorded maximum grain yield which was on par with $I_3$ x $N_3$, $I_2$ x $N_4$ and $I_2$ x $N_3$ and was significantly higher than other treatment combinations. The higher yield in these treatment combinations were attributed to significantly higher grain weight, grains ear$^{-1}$ and grain number m$^{-2}$.

The higher total dry matter and its distribution to cob was mainly responsible for increase in yield in these interactions. Increase in total dry matter (g plant$^{-1}$) lead to increase in biomass per unit area as compared to other treatment combinations. The results are in accordance with the findings of Singh (1991) and Pang *et al.* (1997 a).

Further, soil moisture use is also considered to increase the yield of these treatments. Increase in irrigation from $I_1$ to $I_3$ with increase in nitrogen level from $N_1$ to $N_4$ lead to greater use of available soil moisture. However, maximum water use efficiency was recorded in $I_2$ x $N_3$ treatment combination. Added to this, this treatment combination also registered higher crop nitrogen uptake, accumulation of $NO_3$ nitrogen in soil at physiological maturity, besides minimum drainage and leaching losses.

The higher net return (Fig. 12) of Rs.29213 ha$^{-1}$ and B:C ratio of 2.88 was recorded at $I_3$ x $N_3$ treatment combination due to higher grain yield of $I_2$ x $N_3$ over other treatments.

### 5.3.5 Interaction effect of plant density and nitrogen levels

The interaction effect of plant density and nitrogen level on grain yield (Fig. 13, Plates 4, 5 and 6) on maize was significant. The increase in grain yield due to increase in nitrogen was greater at higher plant density than at lower plant density. However, interaction of plant density at 111111 plants ha$^{-1}$ with nitrogen level of 225 kg ha$^{-1}$ ($N_3$) recorded maximum grain yield (8037 kg ha$^{-1}$). The maximum grain yield at $P_3$ x $N_3$ is attributed to higher grain number m$^{-2}$. Though the grain weight and grains ear$^{-1}$ were lower in this treatment combination, the higher number of plants ha$^{-1}$ is more than compensated to produce more grain number m$^{-2}$ and resulted in higher grain yield. The results are in conformity with the findings of many workers (Setty, 1981; Shridhar *et al.*, 1991a; Shridhar *et al.*, 1991b; and Bangarwa *et al.*, 1992).

The water use efficiency at $P_3$ x $N_3$ was relatively higher as compared to other interactions due to higher grain yield and effective use of available water. In addition, the crop nitrogen uptake was significantly higher in $P_3$ x $N_3$ and was better in nutrient use as reflected by $NO_3$ nitrogen accumulation. Further, $P_3$ x $N_3$ treatment combination also recorded higher net return of Rs.27,823 ha$^{-1}$, which is mainly attributed to higher grain yield ha$^{-1}$.

### 5.3.6 Interaction effect of irrigation scheduling, plant density and nitrogen levels

The interaction effect of irrigation scheduling, plant density and nitrogen levels differed significantly with respect to grain yield. Increase in irrigation scheduling based on IW:CPE ratio from $I_1$ (0.6) to $I_2$ (0.9), plant density from $P_1$ (55555, plants ha$^{-1}$) to $P_3$ (111111 plants ha$^{-1}$) and nitrogen level from $N_1$ (75 kg ha$^{-1}$) to $N_3$ (225 kg ha$^{-1}$) significantly increased the grain yield (Fig.15). Significantly higher grain yield was recorded at treatment combination of irrigation scheduling at 0.9 IW: CPE ratio with plant density of 111111 plants ha$^{-1}$ and application of 225 kg N ha$^{-1}$ ($I_2$ x $P_3$ x $N_3$). The variation in grain yield due to interaction of irrigation scheduling, plant density and nitrogen level was attributed to differences in yield attributing characters and total dry matter production and its distribution to cob (fig.14). At 0.6 IW:CPE ratio irrigation, significantly higher grain yield was obtained for 150 kg N ha$^{-1}$ at all levels of plant densities. But, significantly higher grain yield was obtained at $I_1$ x $P_3$ x $N_2$ combination. At 0.9 IW:CPE ratio irrigation scheduling, at normal plant density

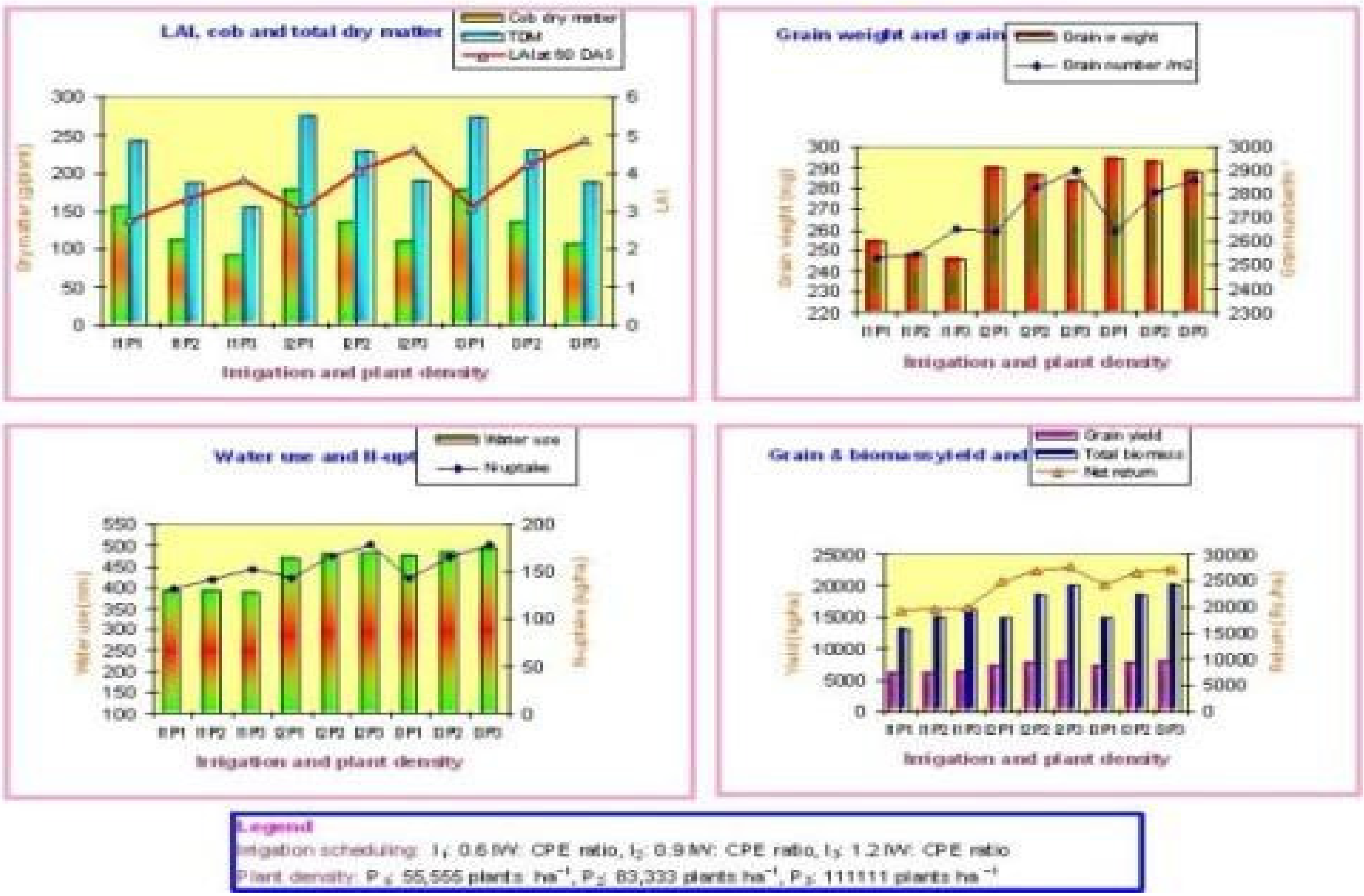



**Fig 11. Effect of irrigation scheduling and plant density on growth, yield, water use, nitrogen uptake and net return of maize**

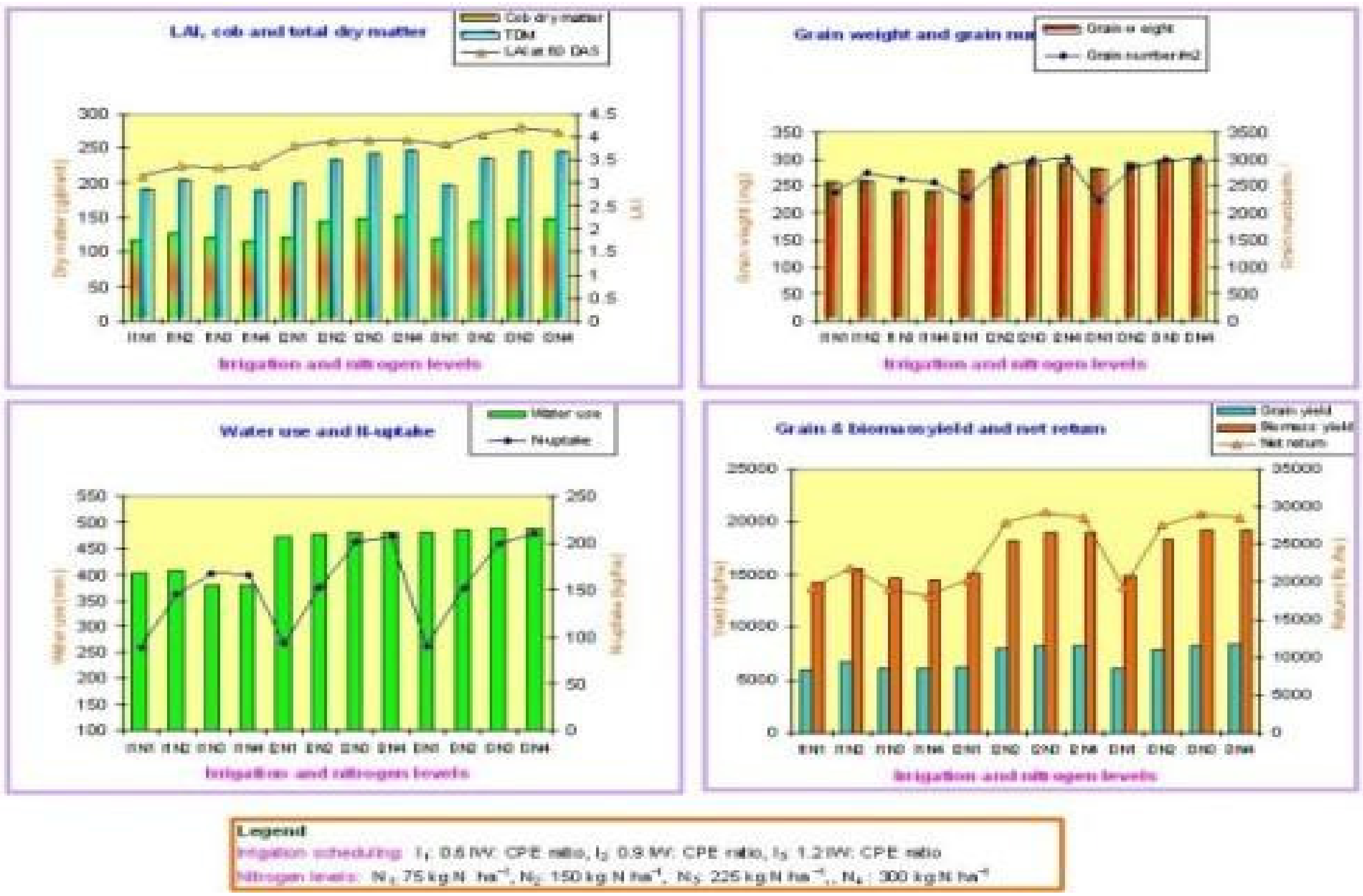



**Fig 12. Effect of irrigation scheduling and nitrogen levels on growth, yield, water use, nitrogen uptake and net return of maize**

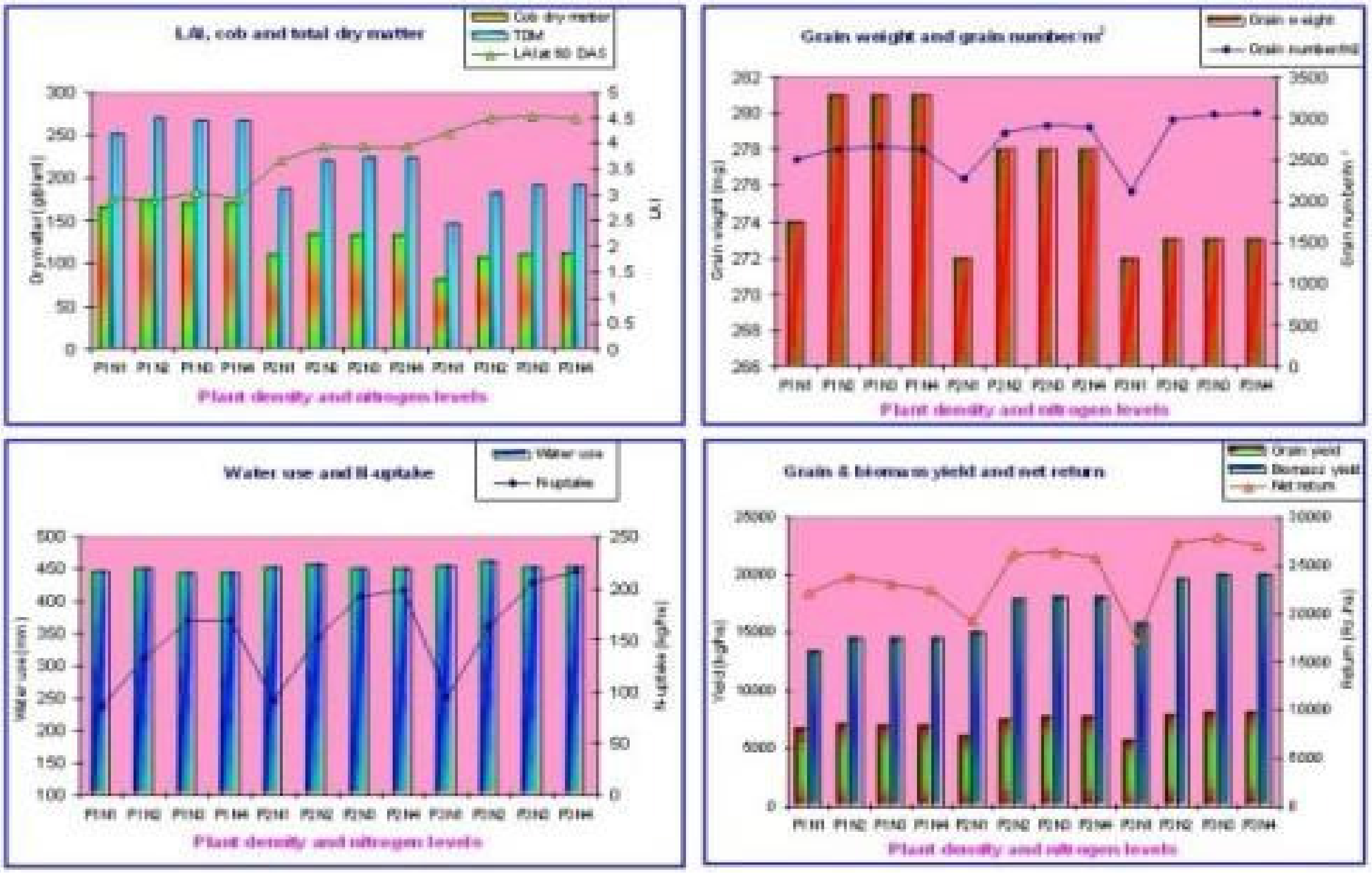



**Fig 13. Effect of plant density and nitrogen levels on growth, yield, water use, nitrogen uptake and net return of maize**

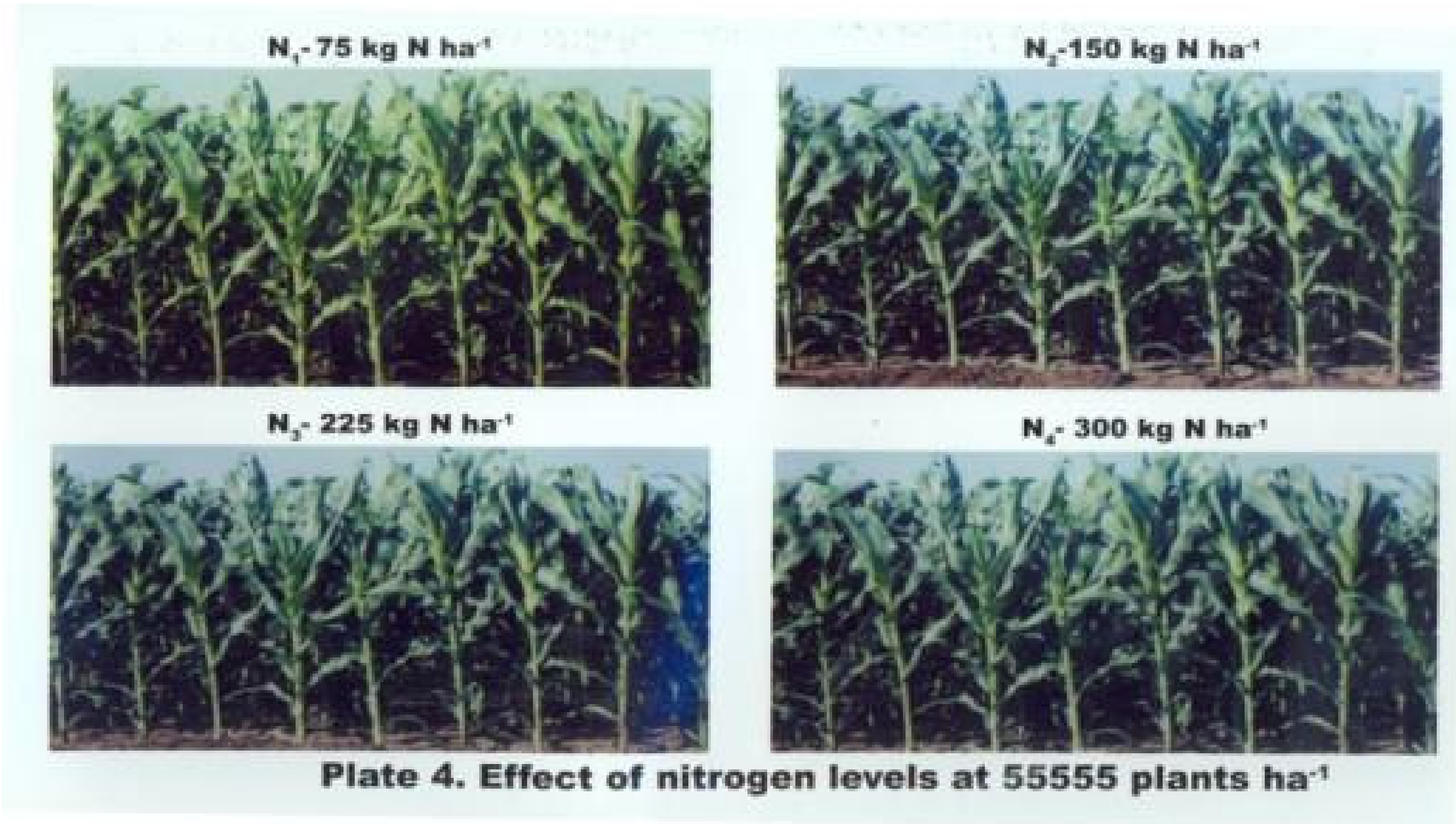



Plate 4. Effect of nitrogen levels at 55555 plants ha$^{-1}$

Plate 4. Effect of nitrogen levels at 55555 plants ha$^{-1}$

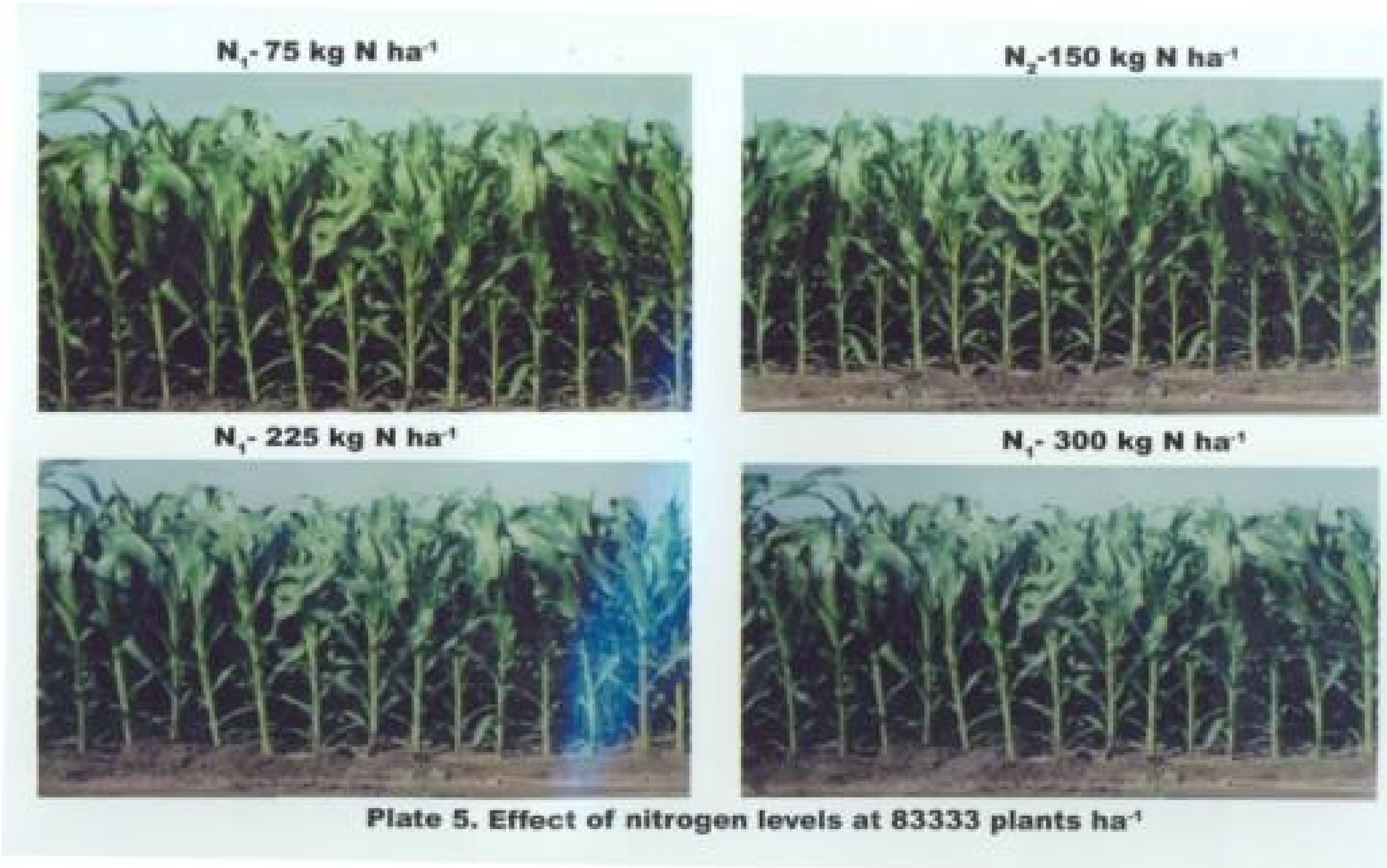



Plate 5. Effect of nitrogen levels at 83333 plants $ha^{-1}$

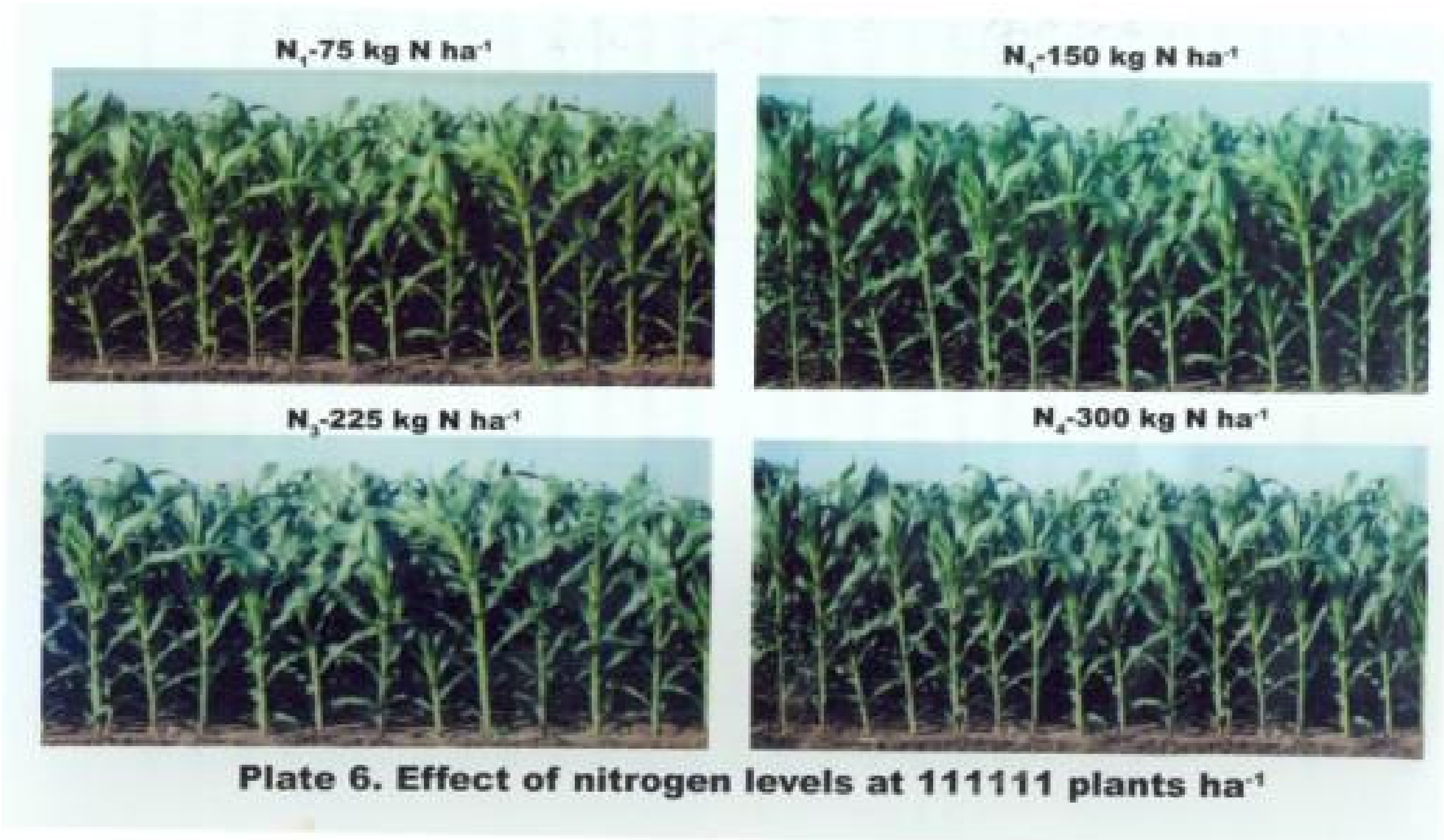



Plate 6. Effect of nitrogen levels at 111111 plants ha$^{-1}$

of 55555 plants $ha^{-1}$ application of 150 kg N $ha^{-1}$ was sufficient to obtain higher yield, while at high (83333 plants $ha^{-1}$) and very high (111111 plants $ha^{-1}$) plant densities application of 225 kg $ha^{-1}$ recorded higher grain yield. Further increase in irrigation scheduling from 0.9 to 1.2 IW:CPE ratio and nitrogen level beyond $N_2$ at normal plant density ($P_1$) , beyond $N_3$ at high ($P_2$) and very high ($P_3$) plant densities did not increase the grain yield. This differential response was due to difference in yield attributing characters (Fig.14). The results are in conformity with the findings of many studies (Tripathi, 1971; Verma and Singh, 1976; Keating *et al.*, 1988).

The higher grain yield of $I_2$ X $P_3$ X $N_3$ treatment combination is also attributed to effective use of available water as evident from the water use efficiency (18.24 kg $ha^{-1}$ $mm^{-1}$) and applied nitrogen as noticed in nitrogen uptake, $NO_3$ nitrogen accumulation and $NO_3$ leaching.

The maximum net return (Fig.15) of Rs.31959 $ha^{-1}$ and higher B:C ratio of 2.96 obtained in $I_2$ x $P_3$ x $N_3$ treatment combination could be attributed to higher grain yield.

## 5.4 EVALUATION OF DSSAT v 3.5 CERES-MAIZE MODEL

Evaluation of DSSAT v 3.5 CERES-MAIZE simulation model involves establishing confidence in its capability to predict outcome experienced in the real world. As a part of the simulation studies, genetic coefficients for different genotypes under study were calibrated with the measurements conducted during 1998-99 season at Agriculture College Farm, Dharwad. The genetic coefficients used in simulating the growth and yield of maize varieties are $P_1$, $P_2$ $P_5$, $G_2$, $G_3$ and PHINT, the corresponding values of Deccan-103 were 280, 0.52, 940, 690, 6.5 and 48; for DMH-1, 280, 0.52, 940, 730, 7.0 and 48; for DMH-2, 275, 0.52, 1030, 730, 7.0 and 48; for Prabha (G-57), 280, 0.52, 945, 720, 5.8 and 48; and for Renuka (G-25) 120, 0.30, 750, 719, 5.7 and 48 respectively. Based on these genetic coefficients and other inputs such as weather, soil experimental and management data, CERES-maize model was evaluated for simulation of growth and yield of maize. The comparison of measured and model predicted data on growth and yield attributes were made to know the capability of the DSSAT v 3.5 CERES-maize model for variation and tendency towards over prediction or under prediction.

### 5.4.1 Simulation: Planting dates and varieties

The response of maize varieties to planting dates during winter under irrigated conditions was simulated. The CERES-maize model over and above predicted more number of leaves (Fig.16) which varied from 1.05 to 2.91 leaves $plant^{-l}$ and this was 11.65 to 16.34 per cent over prediction and the model prediction was more than the real value.

The leaf area index values simulated by the CERES-model (Fig.17), were very close to the measured values (as indicated by RMSE value of 0.04 to 0.08 at different stages). The model over predicted the LAI, the tendency in prediction was accurate, since the CRM values ranged from 1.41 to 8.44 per cent respectively and which were well with in the permissible limit of 10 per cent.

The phenological stages such as days to 50 per cent flowering and days to physiological maturity predicted by the CERES maize (Fig.18) model as indicated by RMSE and CRM values are very close to measured values. The tendency in prediction with respect to 50 per cent flowering was between 0.91 and 1.20 per cent, and for days to physiological maturity was 0.16 to 0.36 per cent. This indicated that the CERES-maize model is very precise in predicting the phenological stages of maize crop.

The grain yield predicted by CERES maize model (Fig.19) was very close to measured values in the range of 154.84 to 197.84 kg $ha^{-1}$ variation and was 1.21 to 1.78 per cent over estimation. Similarly stover yield prediction was also very close to measured values ranging from 266.39 to 287.72 kg $ha^{-l}$ variation and the tendency was 3.64 to 3.81 per cent over prediction. The predicted biomass (Fig.19) was in the range of 380.27 to 395.59 kg $ha^{-l}$ variation and works out to 2.66 to 2.47 per cent over estimation. The harvest index was very close to measured values and it ranged from 1.03 to 1.43 per cent under predicted.

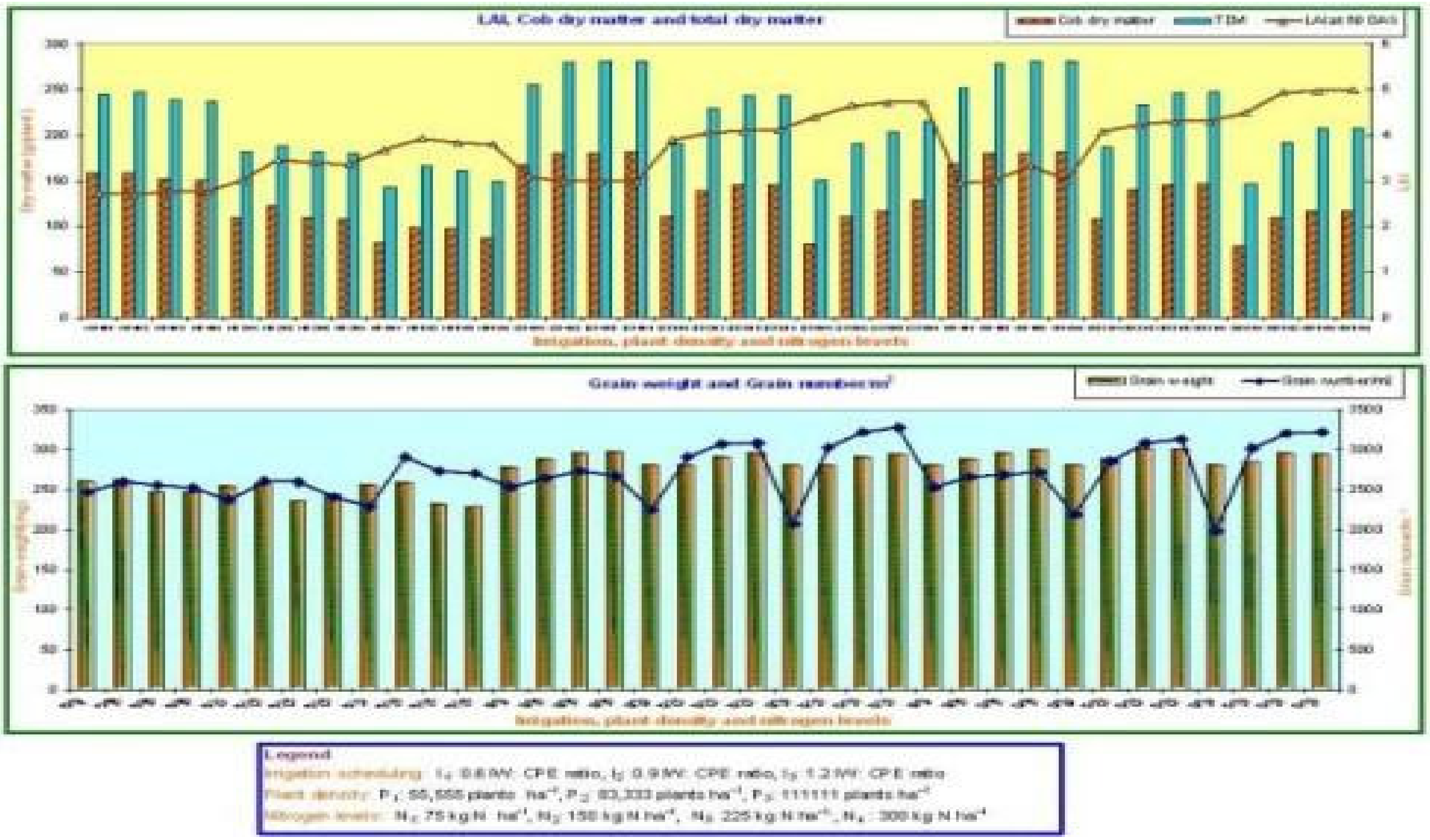



**Fig 14 . Effect of irrigation scheduling, plant density and nitrogen levels on LAI at 60 DAS, cob dry matter, TDM, grin weight and grin number/M$^2$ at harvest of maize**

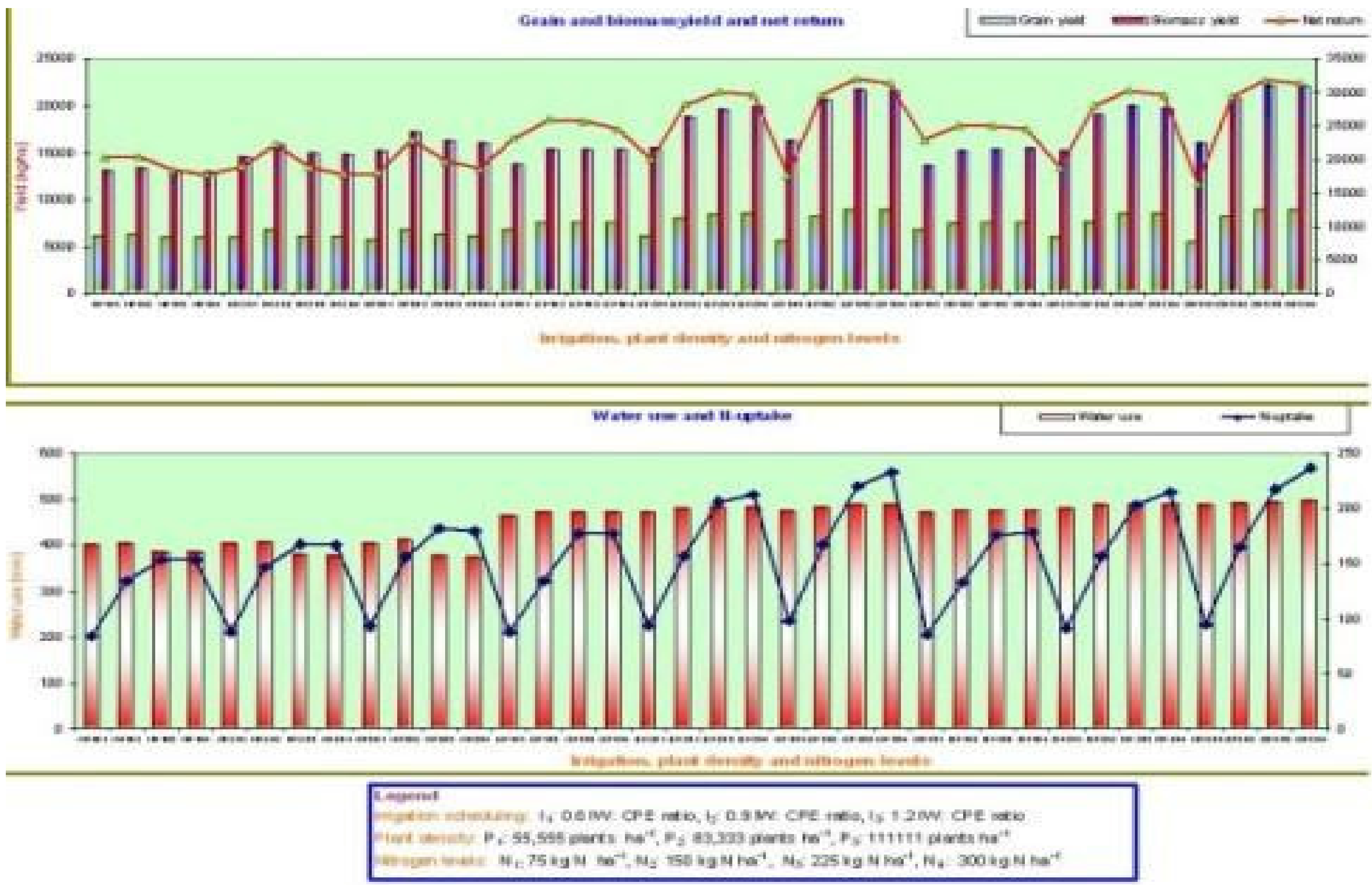


**Fig.15. Effect of irrigation scheduling, plant density and nitrogen levels on grain and biomass yield, net return, water use nitrogen uptake of maize**

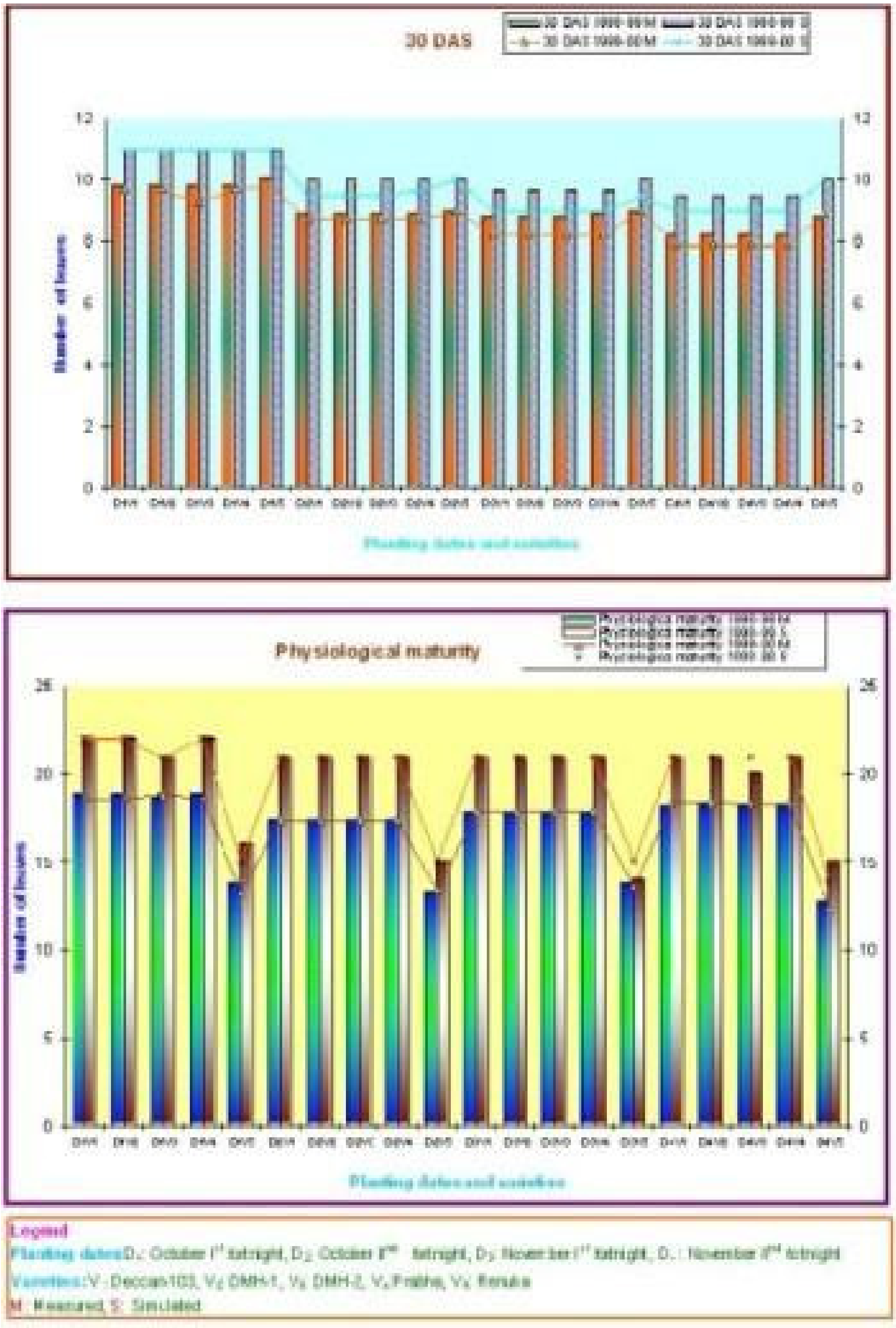



**Fig 16. Measured and simulated number of leaves of maize varieties at different growth stages as influenced by Planting Dates,**

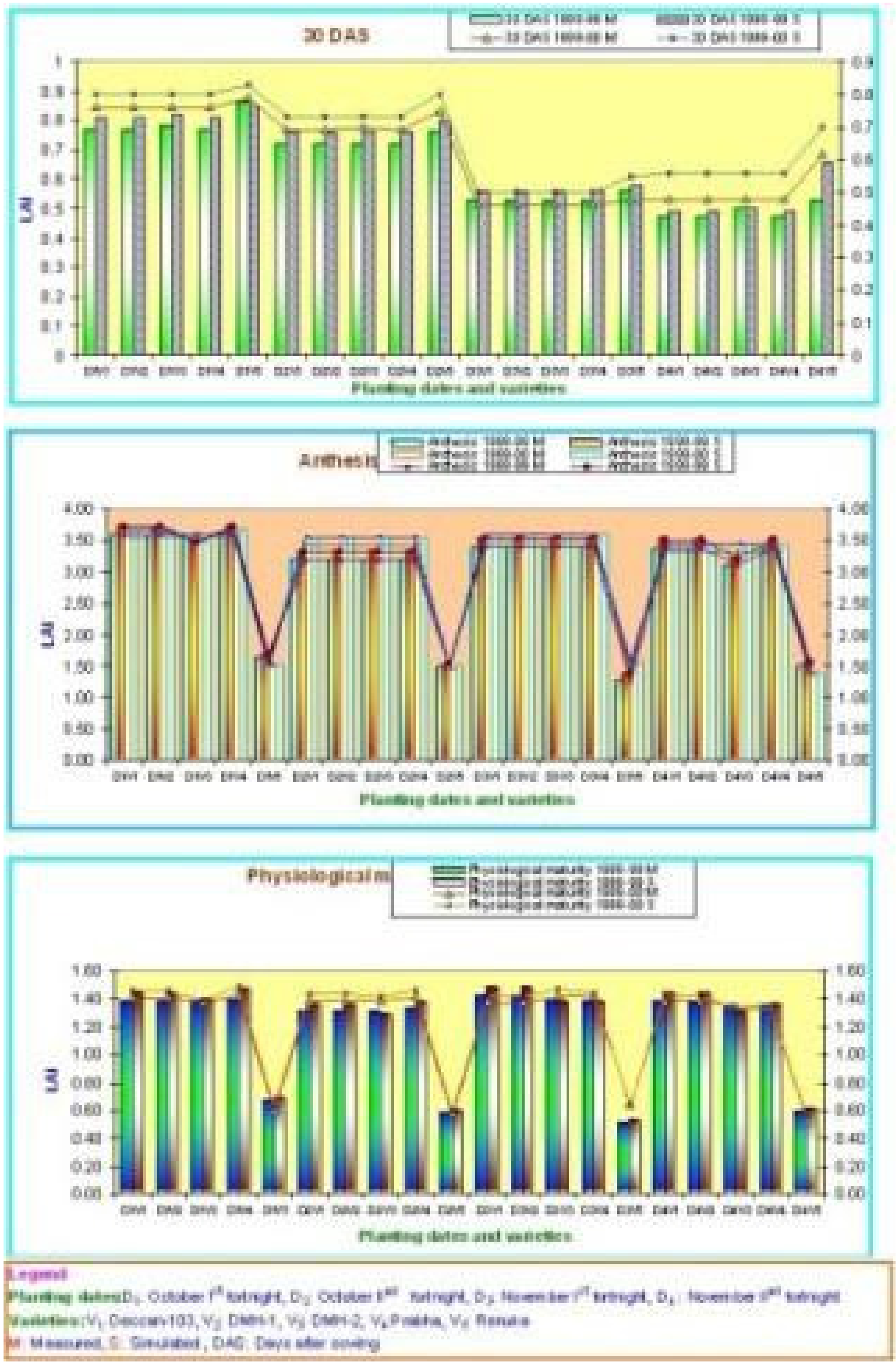



**Fig 17. Measured and simulated LAI of maize varieties at different growth stages as influenced by planting dates**

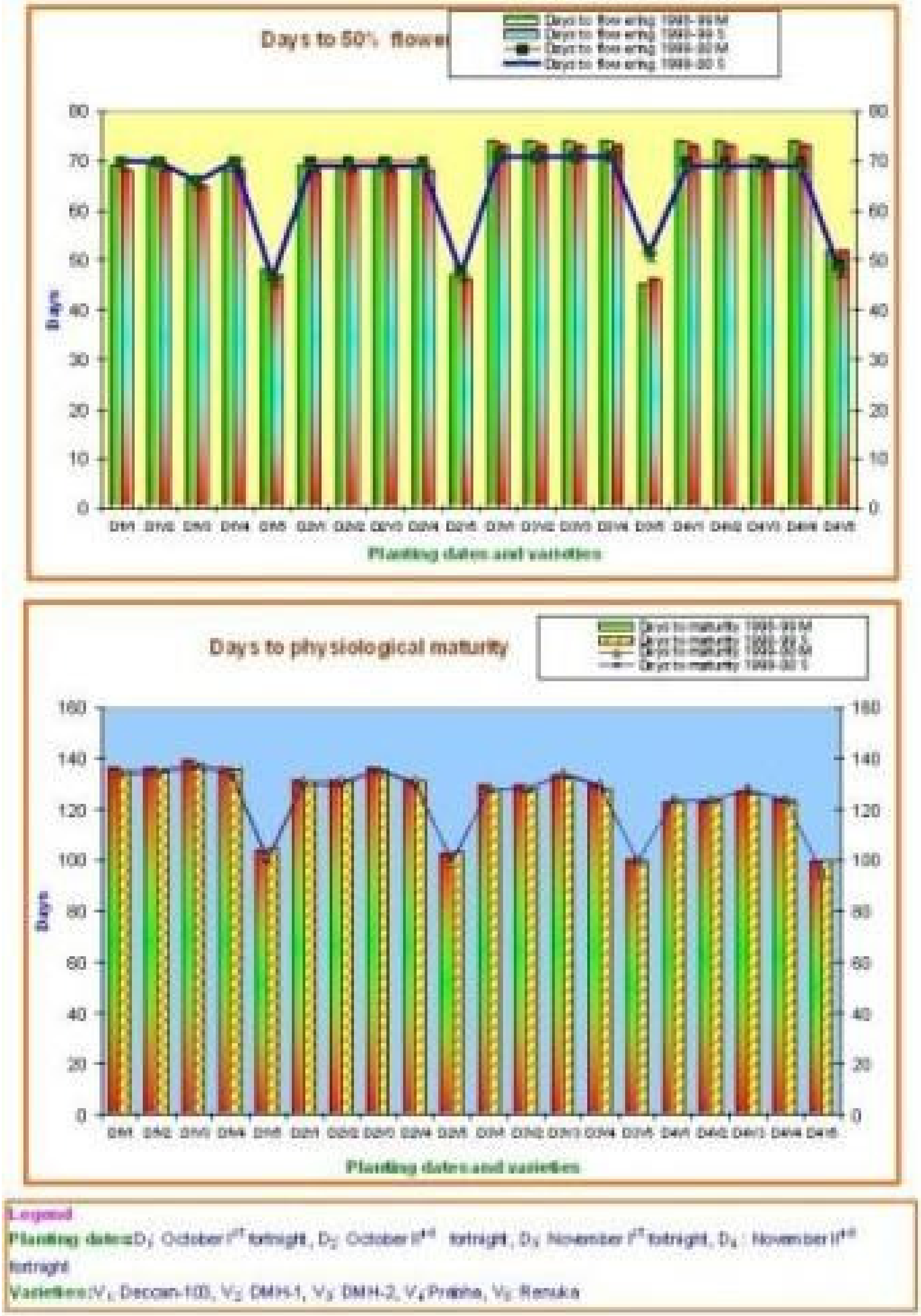



**Fig 18. Measured and simulated days to 50% flowering and physiological maturity of maize varieties as influenced by planting dates**

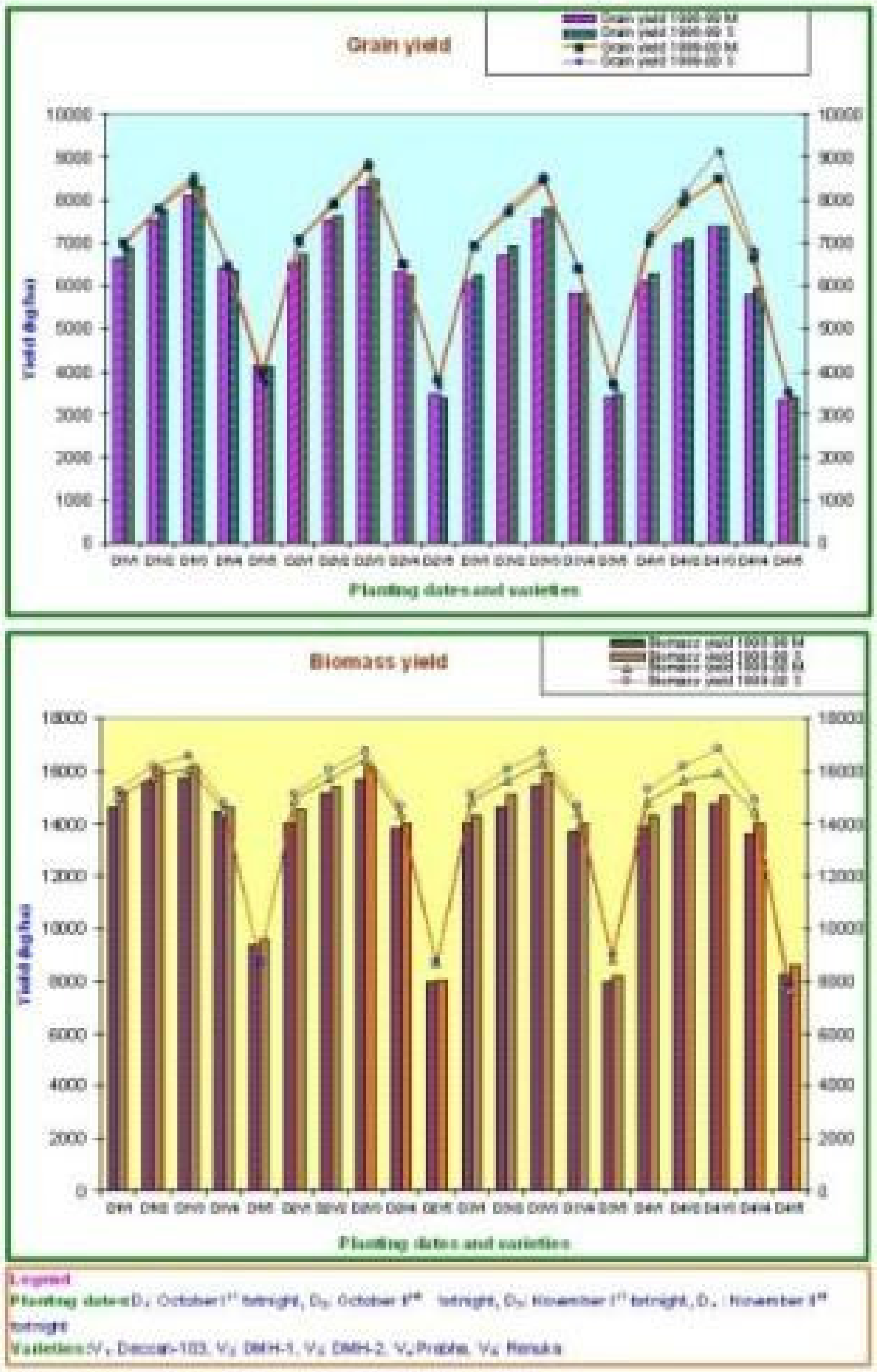



**Fig 19. Measured and simulated grain and biomass yield of maize varieties as influenced by Planting Dates.**

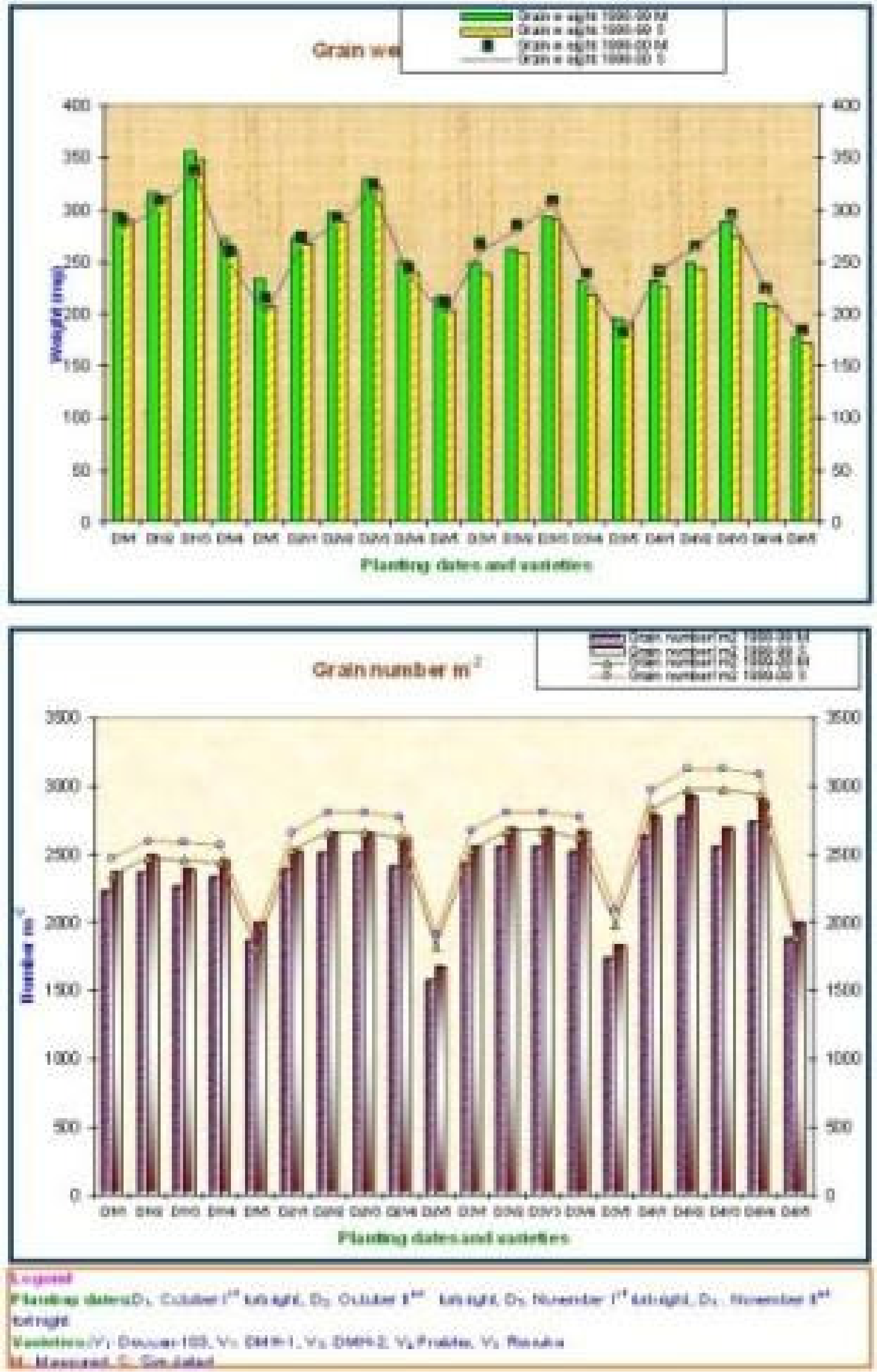



**Fig 20. Measured and simulated grain weight and grain number m-2 of maize varieties as influenced by planting dates**

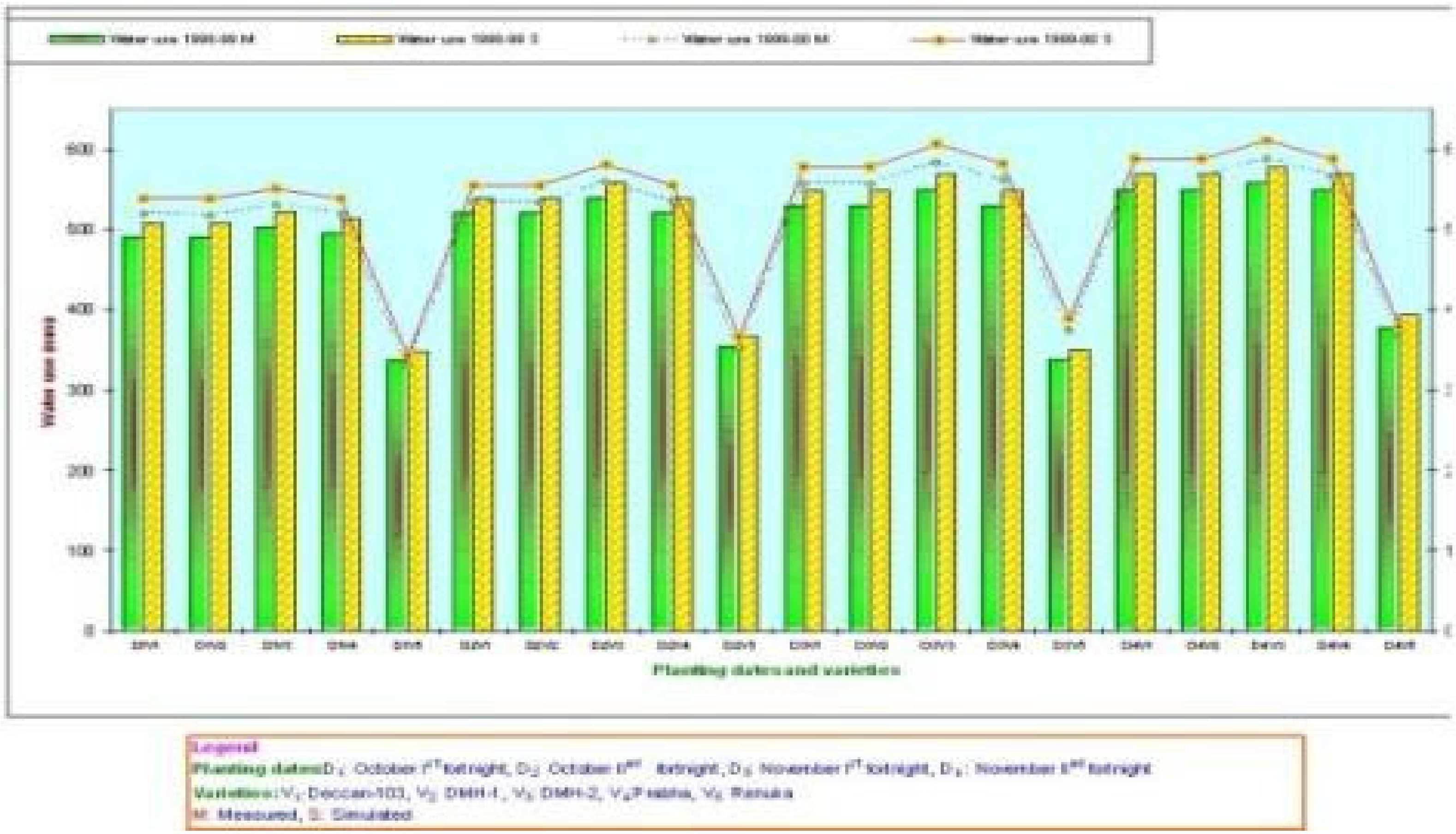



**Fig 21. Measured and simulated water use of maize varieties as influenced by planting dates.**

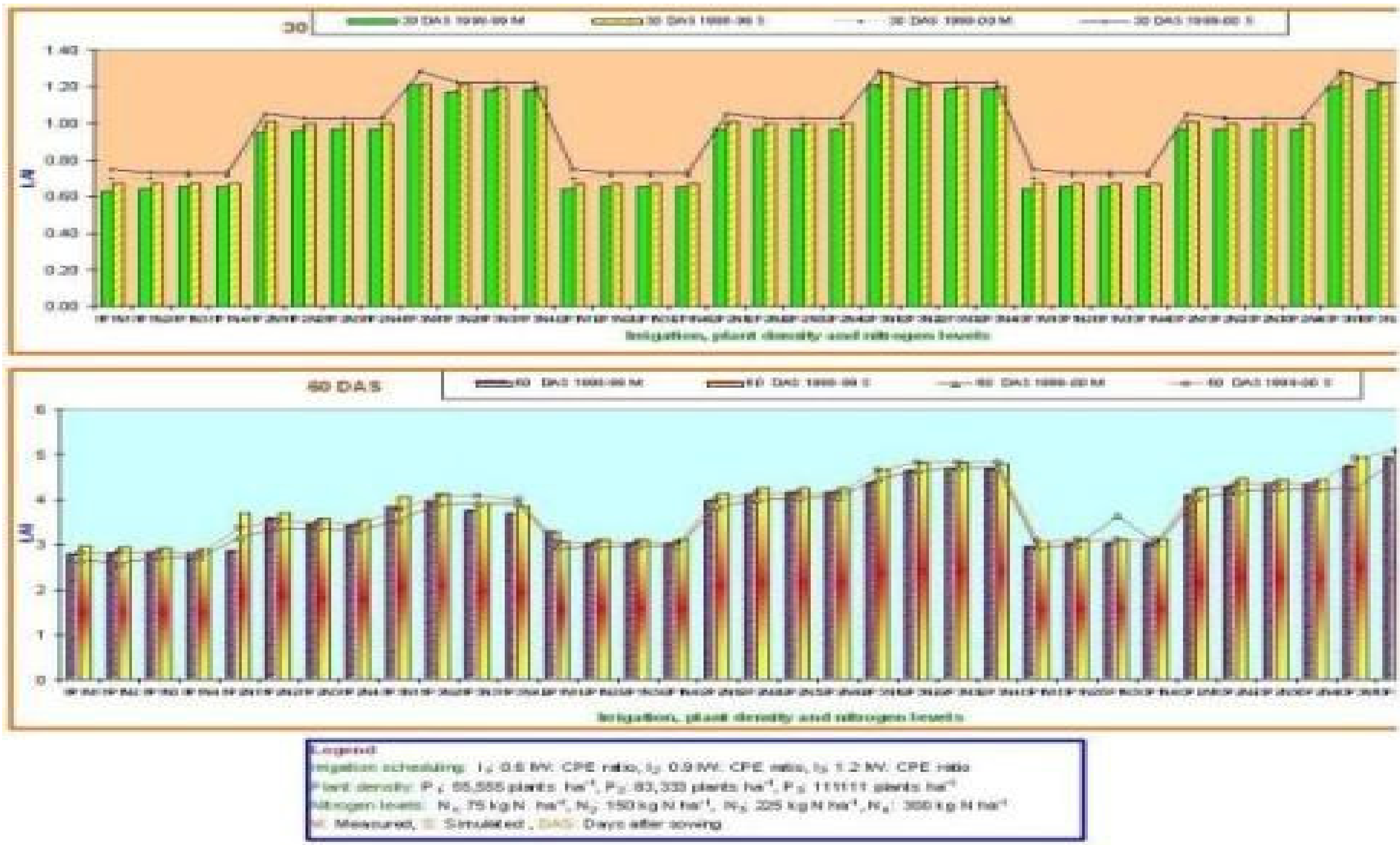


**Fig 22. Measured and simulated LAI of maize at 30 and 60 DAS as influenced by irrigation scheduling, plant density plant and nitrogen levels**


**Fig 23. Measured and simulated grain and biomass yield of maize as influenced by irrigation scheduling, plant density and levels.**

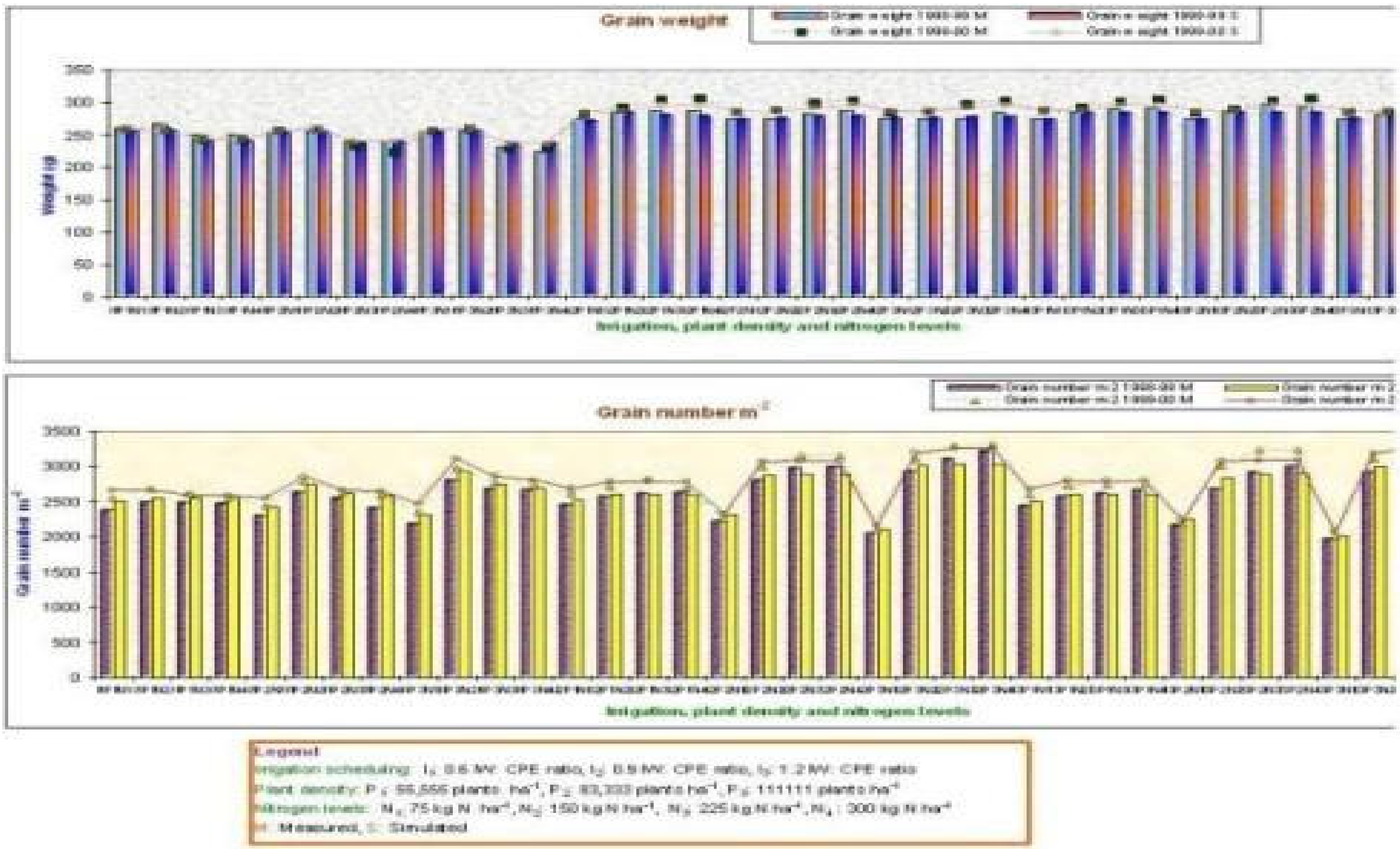



**Fig 24. Measured and simulated grain weight and grain number m-2of maize as influenced by irrigation scheduling, plant density and nitrogen levels.**

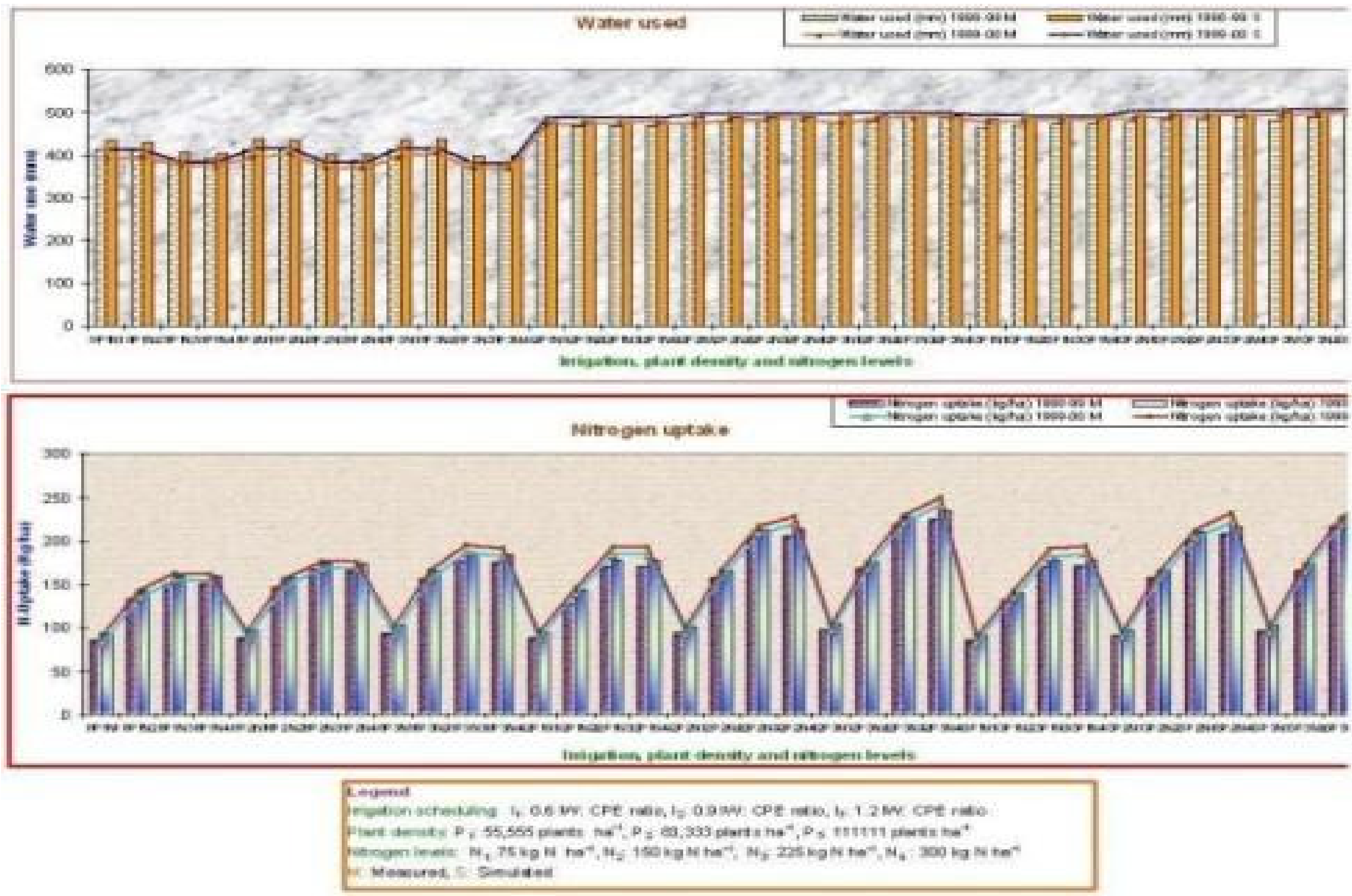


Fig 25.  Measured and simulated water use and nitrogen uptake of maize as influenced by irrigation scheduling plant density and nitrogen levels.

The single grain weight (mg) predicted (Fig.20) was very closer to measured values and the variation was 7.86 to 10.44 mg grain$^{-l}$ and the model under predicted in the range of 2.59 to 3.43 per cent.

The grains ear$^{-l}$ simulated was very close to measured value, Variation was 26 to 26.34 grains ear$^{-l}$ and the tendency of prediction was in the range of 5.76 to 6.09 per cent over estimation.

The mean simulated number of grains m$^{-2}$ were very close to the measured value and the variation was 130.63 grains number m$^{-2}$ and the prediction was over estimated in the range of 5.18 to 5.69 per cent.

The water use (mm) by the crop (Fig.21) was also very precisely predicted. The variation was 18.76 to 19.66 mm, and the model over estimated in the range of 3.78 to 3.79 per cent.

### 5.4.2 Simulation: Irrigation scheduling, plant density and nitrogen levels

The CERES maize model simulated the effect of irrigation scheduling, plant density and nitrogen levels on growth and yield of maize crop over two seasons.

The LAI predicted by the CERES-maize (Fig.22) model due to the effect of irrigation scheduling, plant density and nitrogen levels over the season was very accurate. The deviation was minimum of 0.03 to maximum 0.20. At all the stages, the model over predicted the LAI in the range of 2.76 to 4.11 per cent.

The grain yield predicted by the model (Fig.23) was accurate as the variation was hardly 298.45 to 358.79 kg ha$^{-l}$. The tendency of the model prediction was over estimation in the range of 3.12 to 3.83 per cent.

The CERES-maize model simulated the stover yield, the variation was 314 to 359.25 kg ha$^{-l}$ and indicated that the model was very robust in prediction of stover yield. The model over estimated the stover yield in the range of 2.75 to 3.33 per cent.

Total biomass predicted by CERES-maize model (Fig.23) deviated from 624.43 to 656.86 kg ha$^{-l}$. The predicted values are very close to measured values. The model was accurate in predicting the total biomass yield. Added to this, the biomass yield was over predicted by the model in the range of 3.24 to 3.26 per cent.

Predicted values of harvest index by CERES maize model were closer to measured values with variation of 0.01. The model over-estimated (0.50%) and under-estimated (0.04%) the harvest index.

The variation of predicted values of grain weight (Fig.24) 5.54 to 6.20 mg grain$^{-1}$. The CERES maize prediction was accurate. The model under predicted the grain weight in the range of 0.54 to 0.77 per cent.

The grains ear$^{-1}$ was very accurately predicted by the CERES maize model with a variation of 22.98 to 28.67 grains ear$^{-1}$. The simulated grains ear$^{-1}$ were over estimated in the range of 2.52 to 4.51 per cent.

The CERES-maize predicted grain number m$^{-2}$ (Fig.24) was accurate and variation was in the range of 89.49 to 98.64 grain number m$^{-2}$. The predicted values were over-estimated in the range of 1.25 to 1.63 per cent.

The water used by the crop was simulated by the CERES-maize model (Fig.25), which was accurate since the variation was 13.75 to 14.45 mm. The model over estimated the water used (mm) in the range of 2.88 to 3.02 per cent.

The crop nitrogen uptake predicted by the CERES maize model (Fig.25) was very precise and the variation was 8.61 to 8.65 kg ha$^{-l}$. The model over estimated the nitrogen uptake in the range of 5.41 to 5.53 per cent.

## 5.5 RESULTS OF PRACTICAL UTILITY

The results of practical utility from two field experiments conducted during winter seasons of 1998-99 and 1999-2000, and DSSAT v 3.5 CERES-maize model simulation studies are as follows.

1. DMH-2 performed better than DMH-1 and Deccan-103 hybrids, Prabha (G-57) and Renuka (G-25) composites.
2. October I fortnight to October II fortnight planting dates are suitable for obtaining higher grain yield and net returns of maize during winter season.
3. DMH-2 out yielded to other varieties in all the planting dates. Planting of DMH-2 either during October I fortnight or October II fortnight produced higher grain yield and net returns.
4. Scheduling of irrigation to maize crop during winter season at 0.9 IW:CPE ratio recorded higher grain yield and net returns, besides minimizing drainage and $NO_3$ leaching.
5. Maize crop under high input use (water and nitrogen) responded well to high plant density, recorded higher grain yield and net returns at plant density of 111111 plants $ha^{-l}$ as compared to recommended plant density of 55555 plants $ha^{-l}$.
6. Application of 225 kg N $ha^{-1}$ recorded higher grain yield and net returns over recommended dose of 150 kg N $ha^{-l}$.
7. Due to interaction of irrigation scheduling, plant density and nitrogen level the treatment combination of irrigation scheduling at 0.9 IW/CPE ratio with plant density of 111111 plants $ha^{-1}$ and nitrogen level of 225 kg $ha^{-1}$ recorded higher grain yield of 8886 kg $ha^{-l}$ and net return of Rs.31959 $ha^{-1}$ and B:C ratio of 2.96.
8. The genetic coefficients generated with the help of GENCALC are used to predict the growth and yield of maize with minor variation and permissible tendency (<10 percent) either towards over estimation or under estimation.
9. The DSSAT v 3.5 CERES-maize model simulated the effect of planting dates on growth and yield of maize varieties, and the effect of irrigation scheduling, plant density and nitrogen levels on growth and yield of maize very accurately with in the permissible tendency (less than 10 per cent) towards over estimation and under estimation in respect of LAI, phenological stages such as 50 per cent flowering and physiological maturity, grain yield, stover yield, total biomass, harvest index, grain weight, grains $ear^{-1}$, grain number $m^{-2}$, water used and nitrogen uptake. However, leaf number per plant was little overestimated (more than 10 per cent). In addition, the model also simulated the $NO_3$ nitrogen accumulation, drainage water (mm) and $NO_3$ leaching, which are helpful in interpretation of input use such as water and nitrogen. Hence, the model is very robust in predicting the growth and yield of maize and could be used at wider perspective.

## 5.6 FUTURE LINE OF WORK

1. Single cross hybrids both private and public sector needs to be studied for different management strategies under different eco-systems
2. Genetic coefficients for available genotypes need to be generated
3. Validation of DSSAT v 3.5 CERES maize model under different agro climatic zones is required to identify potential zones to maximize productivity of maize.

# VI. SUMMARY

Maize *(Zea mays* L.) has greater yield potential during winter season which needs to be exploited, so to arrive with the better agro-techniques, two field experiments were planned and conducted during winter seasons of 1998-99 and 1999-2000 at Agriculture College Farm, University of Agricultural Sciences, Dharwad. Further, as simulation models are becoming more accepted cost effective tools for better decision making, evaluation of available simulation model is felt very much needed. Hence, the study on "Studies on optimization of agro-techniques to maximize productivity of winter maize *(Zea mays* L.) and evaluation of DSSAT v 3.5 CERES-maize model" was undertaken.

## 6.1 RESPONSE OF MAIZE VARIETIES TO PLANTING DATES

This field experiment was conducted during winter seasons of 1998- 99 and 1999-2000 in deep vertisol and laidout in split plot design with three replications. The treatments consisted of five varieties namely Deccan-l03, DMH-1, DMH-2, Prabha (G-57) and Renuka (G-25) and four planting dates such as October I fortnight ($D_1$), October II fortnight ($D_2$), November I fortnight ($D_3$ ) and November II fortnight ($D_4$). The results are summarized below.

### 6.1.1 Performance of varieties

Single cross hybrid DMH-2 produced 9, 23, 30 and 122 percent higher yield than DMH-l, Deccan-l03, Prabha and Renuka respectively. DMH-2 recorded significantly higher grain yield (8191 kg ha$^{-1}$) besides higher biomass (15807 kg ha$^{-1}$), grain weight (318 mg grain$^{-1}$) and comparable grains ear$^{-1}$ (466 numbers) and grain number m$^{-2}$ (2579 grains) and registered higher net return (Rs.28830 ha$^{-1}$) and B:C ratio (3.00).

### 6.1.2 Response to planting dates

Planting of maize during October I fortnight recorded higher grain yield (6653 kg ha$^{-1}$) followed by October II fortnight (6630 kg ha$^{-1}$). However November I fortnight and November II fortnight planting recorded relatively lower yield. Further, observed that the climatic condition specially the maximum and minimum temperature, solar radiation were favourable during grain filling period. Hence, these planting dates besides recording higher grain yield resulted in better net return (Rs.21678 and 21480 ha$^{-1}$, respectively) and B:C ratio (2.55 and 2.53 respectively).

### 6.1.3 Response of varieties to planting dates

DMH-2 recorded higher grain yield in all the planting dates from October I fortnight to November II fortnight. DMH-2 planted during October II fortnight recorded significantly higher grain yield, (8553 kg ha$^{-1}$) and next in order were DMH-2 planted during October I fortnight (8255 kg ha$^{-1}$) as compared to other treatment combinations, resulting in higher net return (Rs.30464 and 29145 ha$^{-1}$ respectively) and B:C ratio (3.09 and 3.02 respectively).

## 6.2 EFFECT OF IRRIGATION SCHEDULING, PLANT DENSITY AND NITROGEN LEVELS

The field experiment was conducted in deep vertisol during winter season of 1998-99 and 1999-2000 in split-split plot design and replicated thrice. The treatments consisted of three irrigation levels low 0.6 IW:CPE ratio ($I_1$), normal 0.9 IW:CPE ratio ($I_2$) and high 1.2 IW:CPE ratio ($I_3$); three plant densities normal-55555 plants ha$^{-1}$ ($P_1$), high 83333 plants ha$^{-1}$ ($P_2$) and very high 111111 plants ha$^{-1}$ ($P_3$) and four nitrogen levels, 50 per cent recommended N @ 75 kg ha$^{-1}$ ($N_l$), 100 per cent recommended N @ 150 kg ha$^{-1}$ ($N_2$), 150 per cent recommended N @ 225 kg ha$^{-l}$ ($N_3$) and 200 per cent recommended N @ 300 kg ha$^{-l}$ ($N_4$). The results are summarized below.

### 6.2.1 Response to irrigation scheduling

The increase in irrigation scheduling from $I_1$ (0.6 IW:CPE ratio) to $I_2$ (0.9 IW:CPE ratio) significantly increased the grain yield. Further increase in irrigation had recorded only comparable grain yield. The higher grain yield (7692 kg ha$^{-1}$) at 0.9 IW:CPE ratio was associated with higher growth (LAI, dry matter production g plant$^{-1}$) and yield attributing characters (harvest index, grain weight, grains ear$^{-1}$ and grain number m$^{-2}$). Further, irrigation scheduling at 0.9 IW:CPE ratio efficiently used the available soil water by recording higher grain yield and water use efficiency, and reduced the loss of water through drainage. Efficient use of soil water helped in better utilization of applied nitrogen as shown in crop nitrogen uptake and minimized the loss of nitrogen as depicted by simulated $NO_3$ nitrogen accumulation at physiological maturity and cumulative $N0_3$ leaching. As an economic yardstick the net return (Rs.26472 $ha^{-1}$) and B:C ratio (2.75) were also higher in 0.9 IW:CPE ratio irrigation scheduling.

### 6.2.2 Response to plant density

Under irrigated condition increase in plant density from normal (55,555 plants $ha^{-1}$) to very high (111111 plants $ha^{-1}$) significantly increased the maize yield. Increase in plant density significantly increased the LAI, while decreased the dry matter $plant^{-1}$, grain weight and grains $ear^{-1}$. Increase in plant density increased the grain number $m^{-2}$. Though the individual performance with respect to total dry matter $plant^{-1}$, grain weight and grains $ear^{-1}$ were better at normal density ($P_1$), but grain yield $ha^{-1}$, total biomass $ha^{-1}$ were higher at high and very high plant densities. The high and very high plant densities besides recording higher grain yield and biomass $ha^{-1}$ also used the applied water and nitrogen more efficiently as evidenced by recording higher water use and water use efficiency and lower simulated drainage water loss and higher crop nitrogen uptake leaving smaller amount of applied nitrogen as accumulated $NO_3$ nitrogen at physiological maturity. In addition minimized $NO_3$ leaching. The higher grain yield (7373 kg $ha^{-1}$) and net return Rs.24854 $ha^{-1}$ was recorded at very high plant density($P_3$).

### 6.2.3 Response to nitrogen level

Increase in nitrogen from 50 per cent recommended dose (75 kg $ha^{-1}$) to 150 per cent recommended dose (225 kg $ha^{-1}$) significantly increased the grain yield, further increase to 200 per cent recommended dose (300 kg $ha^{-1}$) did not increase the grain yield significantly. Increase in nitrogen level upto 150 per cent recommended dose increased the growth and yield parameters such as LAI, total dry matter production, grain weight, grains ear-$^1$ and grain number $m^{-2}$. In addition, applied water and nitrogen also better utilized as evidenced by water use and crop nitrogen uptake at increased nitrogen level from 75 to 225 kg $ha^{-1}$. Further, increase in nitrogen at 200 per cent recommended level (300 kg $ha^{-1}$) significantly increased the crop nitrogen uptake, besides recording higher $NO_3$ nitrogen accumulation and $NO_3$ leaching. In this context, application of 225 kg $ha^{-1}$ (150 per cent recommended dose) optimized the grain yield (7591 kg $ha^{-1}$ ) besides effective utilization of applied water and nitrogen, and recorded net return of Rs.25733 $ha^{-1}$.

### 6.2.4 Response to Irrigation scheduling and plant density

Increase in irrigation level from 0.6 ($I_1$) to 0.9 ($I_2$) IW:CPE ratio with increase in plant density from normal ($P_1$) 55555 plants $ha^{-1}$ to very high ($P_3$) 111111 plants $ha^{-1}$ recorded significantly higher grain yield. Maximum grain yield of 7933 kg $ha^{-1}$ was produced at providing irrigation at 0.9 IW:CPE ratio with a plant density of 111111 plants $ha^{-1}$. This treatment combination also recorded higher LAI and grain number $m^{-2}$. The individual plant characters such as total dry matter $plant^{-1}$, grain weight and grains $ear^{-1}$ were higher at low plant density ($P_1$) as compared to high plant density ($P_2$) at same level of irrigation. The higher number of plants per unit area at high plant density caused to achieve maximum grain yield. The water use and water use efficiency were also maximum besides minimum drainage loss. In addition, the crop nitrogen uptake was maximum, while $NO_3$-N accumulation and cumulative $NO_3$ leaching were minimum. Because of higher grain yield (7933 Kg $ha^{-1}$), the treatment combination $I_2$ x $P_3$ recorded higher net return of Rs. 27608 $ha^{-1}$, the B:C ratio for the corresponding treatment was 2.74.

### 6.2.5 Response to irrigation scheduling and nitrogen levels.

The increase in irrigation scheduling from 0.6 IW:CPE ratio ($I_1$) to 0.9 IW:CPE ratio ($I_2$) and nitrogen dose from 50 per cent recommended ($N_1$) to 150 per cent recommended level ($N_3$) significantly increased the grain yield. The treatment combination $I_2$x $N_3$ recorded comparable grain yield with $I_2$ x $N_4$, $I_3$ x $N_3$ and $I_3$ x $N_4$ and recorded higher growth and yield contributing characters such as LAI, total dry matter production, grain weight, grains $ear^{-1}$ and grain number $m^{-2}$. The water use, water use efficiency, crop nitrogen uptake were also higher at $I_2$ x $N_3$ level, while drainage loss, $NO_3$ nitrogen accumulation at physiological maturity and $NO_3$ leaching were minimum. In addition this treatment also recorded higher net return of Rs.29213 $ha^{-1}$ and B:C ratio of 2.88.

### 6.2.6 Response to plant density and nitrogen levels

At normal plant density of 55555 plants $ha^{-1}$ ($P_1$) increase in nitrogen from $N_1$ (75 kg $ha^{-1}$) to $N_2$ (150 kg $ha^{-1}$) significantly increased the grain yield, while at high plant density of ($P_2$) 83333 plants $ha^{-1}$ and very high plant density ($P_3$) of 111111 plants $ha^{-1}$ increase in nitrogen from $N_1$ to $N_3$ (225 kg $ha^{-1}$) significantly increased the grain yield. However among the plant densities and nitrogen interactions maximum grain yield (8037 kg $ha^{-1}$) was recorded with a treatment combination of 111111 plants $ha^{-1}$ ($P_3$) and nitrogen level of 225 kg $ha^{-1}$($N_3$). This treatment combination also recorded higher LAI and grain number $m^{-2}$, though the total dry matter production $plant^{-1}$, grain weight and grains $ear^{-1}$ were lower. Further, the treatment combination $P_2$ x $N_3$ recorded with better resource use such as water and nitrogen as evidenced by higher water use efficiency and crop nitrogen uptake, and minimized drainage loss, $NO_3$ nitrogen accumulation and $NO_3$ leaching. In addition, it also recorded net return of Rs.27823 $ha^{-1}$ and B:C ratio of 2.73.

### 6.2.7 Response to irrigation scheduling, plant density and nitrogen levels.

The grain yield due to interaction of nitrogen at each level of irrigation scheduling and plant density differed significantly. At 0.6 IW:CPE ratio irrigation scheduling, increase in nitrogen from $N_1$(75 kg $ha^{-1}$) to $N_2$ (150 kg $ha^{-1}$) significantly increased the grain yield at all levels of plant densities. Further increase in nitrogen level upto $N_4$ reduced the grain yield. However, at 0.9 ($I_2$) and 1.2 ($I_3$) IW:CPE ratio irrigation scheduling increase in nitrogen from $N_1$ to $N_2$ at $P_1$(normal) plant density, and $N_1$ to $N_3$ at high ($P_2$) and very high ($P_3$) plant densities significantly increased the grain yield. Among the interaction effects a treatment combination of irrigation scheduling of 0.9 IW:CPE ratio with plant density of 111111 plants $ha^{-1}$ and nitrogen level of 225 kg $ha^{-1}$ ($I_2$ x $P_3$ x $N_3$ ) recorded maximum grain yield, LAI and grain number $m^{-2}$.

The treatment combination of $I_2$ x $P_3$ x $N_3$ recorded better resource use as evidenced by water use and crop nutrient uptake resulting in minimum drainage loss, $NO_3$ leaching and $NO_3$ nitrogen accumulation. The net return (Rs.31959 $ha^{-1}$) and B:C ratio (2.96) were also higher under this treatment combination.

## 6.3 Evaluation of DSSAT v 3.5 CERES – maize model

DSSAT v 3.5 CERES – maize model which simulates the growth and yield of maize crop was evaluated during winter seasons of 1988-99 and 1999-2000 at Agriculture College Farm, Dharwad. A validated crop model with genetic coefficients for varieties could be a time and money saving tool, useful for studying response of varieties in contrasting environments and management practices. Information on phenology such as silking and maturity dates, periodical observations on leaf weight, stem weight, number of leaves, above ground biomass and leaf area index and at physiological maturity, grain yield, stover yield, biomass and grains $plant^{-1}$ and weight per grain were used for calibration of model output. Genetic coefficients were generated with the help of GENCALC programme. These genetic constants for individual variety were used for simulation studies of 1998-99 and 1999-2000 cropping seasons. The model simulated the number of leaves $plant^{-1}$, LAI, above ground biomass, phenological stages, grain yield, stover yield, weight per grain, grains $ear^{-1}$, grain number $m^{-2}$, water used, and nutrient uptake and, these simulated values were compared with measured data and summarized here under.

### 6.3.1 Simulating the response of maize varieties to planting dates.

CERES –maize model simulated the response of maize varieties to planting dates during winter season under irrigated condition. The simulated data on leaf area index, days to 50% flowering, day to physiological maturity, grain yield, stover yield, biomass yield, weight per grain, grains $ear^{-1}$, grain number $m^{-2}$, harvest index and water use were compared with measured data. The DSSAT v 3.5 CERES-maize model predicted the growth and yield parameters very accurately as the RMSE values were very closer to the measured values.

The root mean square error values for leaf area index (0.04 to 0.12), days to 50% flowering (0.78 to 0.95 days) days to physiological maturity (0.74 to 0.84 days), grain yield (154.84 to 197.84 kg $ha^{-1}$), stover yield (266.39 to 287.72 kg $ha^{-1}$), total biomass (380.27 to 395.59 kg $ha^{-1}$), harvest index (0.006 to 0.009), weight per grain (7.87 to 10.44 mg), grains $ear^{-1}$ (26 to 26.34 grains), grain number $m^{-2}$ (130.63 grains) and water use (18.76 to 19.66 mm) are calculated. In addition, the CRM values which indicated the tendency of the model to its prediction for most of these yield and yield attributing characters were within 5 per cent deviation from the measured values. The CERES – maize model predicted the number of leaves plant $^{-1}$ with variation more than 10 per cent, hence the model needs precise calibration with respect to PHINT value of maize genotypes.

### 6.3.2 Simulating the effect of irrigation scheduling, plant density and nitrogen levels on growth and yield of maize.

The CERES maize model also simulated the growth and yield of maize crop as influenced by irrigation scheduling, plant density and nitrogen levels. The simulated values were very precise with respect to LAI (RMSE 0.03 to 0.20), grain yield (RMSE 298.45 to 358.79 kg $ha^{-1}$), stover yield (RMSE 314 to 359.25 kg $ha^{-1}$) above ground biomass (RMSE 624.43 to 656.86 kg $ha^{-1}$), harvest index (RMSE 0.01), weight per grain (RMSE 5.54 to 6.20 mg), grains $ear^{-1}$ (RMSE 22.98 to 28.67 grains), grain number $m^{-2}$ (RMSE 89.49 to 98.64 grains $m^{-2}$), water used (RMSE 13.75 to 14.45 mm), crop nitrogen uptake (RMSE 8.61 to 8.65 kg $ha^{-1}$). Further, the CRM was also calculated to know the tendency of the model prediction and the values were within 10 percent. The model very accurately predicted the simulated values. In addition, the drainage loss, $NO_3$ nitrogen accumulation in soil and $NO_3$ leaching were simulated with the assumption that since the model predicted very precisely the growth and yield of maize crop. The drainage, $NO_3$ nitrogen accumulation and $NO_3$ leaching predicted values helped in interpretation and understanding the resource use such as water and nitrogen.

# VII. REFERENCES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**Appendix 1. Monthly mean (1998-99 and 1999-2000) and average (48 years from 1950-1997) meteorological data, Agricultural College Farm, Dharwad.**

| Months | Solar Radiation $MJm^{-2}d^{-1}$ | | | | Air Temperature (°C) Maximum | | | | Air Temperature (°C) Minimum | | | | Rainfall (mm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998 | 1999 | 2000 | 1950-97* | 1998 | 1999 | 2000 | 1950-97 | 1998 | 1999 | 2000 | 1950-97 | 1998 | 1999 | 2000 | 1950-97 |
| January | 15.30 | 19.00 | 20.00 | - | 30.5 | 29.4 | 30.6 | 29.13 | 15.40 | 12.4 | 15.0 | 14.11 | 000.00 | 000.00 | 00.00 | 000.11 |
| February | 20.40 | 21.00 | 22.50 | - | 32.20 | 32.80 | 31.10 | 34.76 | 15.70 | 16.90 | 15.70 | 15.94 | 000.00 | 000.00 | 00.00 | 000.00 |
| March | 21.00 | 22.90 | 23.60 | - | 35.80 | 36.20 | 35.20 | 35.76 | 19.1 | 20.20 | 18.50 | 18.76 | 000.00 | 000.00 | 00.00 | 007.77 |
| April | 19.80 | 20.50 | 21.60 | - | 38.30 | 36.60 | 37.30 | 37.09 | 22.10 | 21.10 | 21.30 | 21.37 | 000.00 | 014.70 | 00.00 | 049.51 |
| May | 17.60 | 17.80 | - | - | 35.90 | 32.20 | - | 36.75 | 21.90 | 21.30 | - | 21.45 | 033.20 | 032.80 | - | 087.62 |
| June | 17.20 | 19.60 | - | - | 31.00 | 28.00 | - | 29.47 | 21.20 | 21.00 | - | 21.20 | 222.40 | 071.80 | - | 112.96 |
| July | 15.20 | 15.80 | - | - | 27.60 | 26.40 | - | 27.05 | 21.30 | 20.81 | - | 20.96 | 082.50 | 113.90 | - | 156.03 |
| August | 15.00 | 17.82 | - | - | 27.80 | 27.10 | - | 27.10 | 21.40 | 20.41 | - | 20.64 | 051.40 | 019.70 | - | 102.37 |
| September | 14.60 | 16.50 | - | - | 28.20 | 28.30 | - | 28.75 | 21.00 | 20.00 | - | 20.16 | 214.40 | 008.80 | - | 104.13 |
| October | 16.10 | 16.60 | - | - | 28.60 | 28.70 | - | 30.17 | 20.10 | 19.80 | - | 19.22 | 098.10 | 161.10 | - | 136.62 |
| November | 16.50 | 17.50 | - | - | 29.40 | 29.60 | - | 29.37 | 17.10 | 16.10 | - | 15.33 | 040.20 | 000.00 | - | 035.04 |
| December | 16.90 | 18.30 | - | - | 28.70 | 28.90 | - | 29.17 | 14.00 | 13.40 | - | 13.41 | 000.00 | 000.00 | - | 006.08 |

| | Relative Humidity % | | | | Evaporation (mm $day^{-1}$) | | | | Wind speed Km $hr^{-1}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998 | 1999 | 2000 | 1950-97 | 1998 | 1999 | 2000 | 1950-97* | 1998 | 1999 | 2000** | 1950-97* |
| January | 75 | 75 | 48 | 62.88 | 3.3 | 5.3 | 2.5 | - | 5.2 | 5.4 | - | - |
| February | 69 | 63 | 50 | 50.82 | 4.1 | 6.00 | 3.6 | - | 6.5 | 7.0 | - | - |
| March | 57 | 63 | 45 | 56.48 | 5.2 | 6.90 | 7.2 | - | 7.5 | 8.2 | - | - |
| April | 58 | 65 | 57 | 59.10 | 5.6 | 6.90 | 8.0 | - | 10.5 | 13.1 | - | - |
| May | 65 | 75 | - | 67.10 | 3.9 | 4.40 | - | - | 12.6 | 12.1 | - | - |
| June | 80 | 85 | - | 81.77 | 2.5 | 3.10 | - | - | 14.5 | 16.5 | - | - |
| July | 87 | 89 | - | 88.37 | 1.6 | 1.60 | - | - | 19.6 | 14.6 | - | - |
| August | 88 | 85 | - | 86.83 | 1.2 | 1.30 | - | - | 9.0 | 12.5 | - | - |
| September | 87 | 83 | - | 83.24 | 1.3 | 2.30 | - | - | 7.3 | - | - | - |
| October | 84 | 79 | - | 76.26 | 1.3 | 2.01 | - | - | 5.1 | - | - | - |
| November | 77 | 59 | - | 68.44 | 2.0 | 3.00 | - | - | 5.5 | - | - | - |
| December | 73.00 | 51 | - | 64.69 | 4.2 | 2.40 | - | - | 7.7 | - | - | - |

*- Not available
**- Not recorded

## Appendix 2. Methods adopted in analysis of physical and chemical properties of the experimental site(s) and plant samples

| Sl. No. | Particulars | Values | Method Adopted |
|---|---|---|---|
| **A** | **Physical properties:** | | |
| | 1. Particle size analysis | | International pipette method (Piper, 1966) |
| | a. Coarse sand (%) | 7.5 | International pipette method (Piper, 1966) |
| | b. Fine sand (%) | 14.02 | International pipette method (Piper, 1966) |
| | c. Clay (%) | 50.7 | International pipette method (Piper, 1966) |
| | 2. Soil moisture constants | | |
| | a. Field capacity (%) | 31.00 | Pressure plate apparatus method (Black, 1965) |
| | b. Permanent wilting point (%) | 16.00 | Pressure plate apparatus method (Black, 1965) |
| | c. Bulk density g/cc | 1.27 | Core sampler method (Piper, 1950) |
| **B** | **Chemical properties** | | |
| | 1. Organic carbon(%) | 0.73 | Walkley and Black wet oxidation method (Jackson, 1973) |
| | 2. pH (1:2.5) | 7.9 | Glass electrode pH meter (Piper, 1966) |
| | 3. EC (dsm$^{-1}$) | 0.09 | Conductometric method (Jackson, 1967) |
| | 4. Available nitrogen, kg ha$^{-1}$ | 180 | Modified kjeldhal method (Jackson, 1967) |
| | 5. Available phosphorus, kg ha$^{-1}$ | 31 | Olsen's method (Muhr *et al.*, 1965) |
| | 6. Available potassium, kg ha$^{-1}$ | 300 | Flame photometer method (Muhr *et al.*, 1965) |
| **C** | **Plant Samples** | | |
| | 1. Total nitrogen(%) | - | Micro kjeldhal method (Jackson, 1973) |

## Appendix 3. Details of Irrigation scheduling based on IW/CPE ratio

| Date | Days of year | Days after sowing | $I_1$ = IW/CPE ratio 0.6 | | | $I_2$ = IW/CPE ratio 0.9 | | | $I_3$ = IW/CPE ratio 1.2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Irri. No. | CPE (mm) | Amount (mm) | Irri. No. | CPE(mm) | Amount (mm) | Irri. No. | CPE(mm) | Amount (mm) |
| **1998-99** | | | | | | | | | | | |
| 01.11.1998 | 305 | 0 | 1 | - | 60 | 1 | - | 60 | 1 | - | 60 |
| 03.12.1998 | 337 | 32 | X | X | X | X | X | X | 2 | 50.1 | 60 |
| 08.12.1998 | 342 | 37 | X | X | X | 2 | 66.5 | 60 | X | X | X |
| 15.12.1998 | 349 | 44 | 2 | 100.2 | 60 | X | X | X | 3 | 100.2 | 60 |
| 23.12.1998 | 357 | 52 | X | X | X | 3 | 135.2 | 60 | X | X | X |
| 27.12.1998 | 361 | 56 | X | X | X | X | X | X | 4 | 153.8 | 60 |
| 06.01.1999 | 6 | 66 | 3 | 201.6 | 60 | 4 | 201.6 | 60 | 5 | 201.6 | 60 |
| 16.01.1999 | 16 | 76 | X | X | X | X | X | X | 6 | 253.6 | 60 |
| 20.01.1999 | 20 | 80 | X | X | X | 5 | 269.9 | 60 | X | X | X |
| 25.01.1999 | 25 | 85 | 4 | 302.6 | 60 | X | X | X | 7 | 302.6 | 60 |
| 31.01.1999 | 31 | 91 | X | X | X | 6 | 336.3 | 60 | X | X | X |
| 03.02.1999 | 34 | 94 | X | X | X | X | X | X | 8 | 353.6 | 60 |
| 11.02.1999 | 42 | 102 | 5 | 399.6 | 60 | 7 | 399.6 | 60 | 9 | 399.6 | 60 |
| 20.02.1999 | 51 | 111 | X | X | X | X | X | X | 10 | 453.0 | 60 |
| 22.02.1999 | 53 | 113 | X | X | X | 8 | 466.6 | 60 | X | X | X |
| **Total** | | | **5** | **-** | **300** | **8** | **-** | **480** | **10** | **-** | **600** |
| **1999-2000** | | | | | | | | | | | |
| 01.11.1999 | 305 | - | 1 | - | 60 | 1 | - | 60 | 1 | - | 60 |
| 10.11.1999 | 314 | 10 | 2 | - | 60 | 2 | - | 60 | 2 | - | 60 |
| 27.11.1999 | 331 | 27 | X | X | X | X | X | X | 3 | 52.5 | 60 |
| 02.12.1999 | 336 | 32 | X | X | X | 3 | 66.5 | 60 | X | X | X |
| 15.12.1999 | 349 | 45 | 3 | 100.3 | 60 | X | X | X | 4 | 100.3 | 60 |
| 31.12.1999 | 365 | 61 | X | X | X | 4 | 134.8 | 60 | X | X | X |
| 08.01.2000 | 08 | 69 | X | X | X | X | X | X | 5 | 150.4 | 60 |
| 27.01.2000 | 27 | 88 | 4 | 200.3 | 60 | 5 | 200.3 | 60 | 6 | 200.3 | 60 |
| 11.02.2000 | 42 | 103 | X | X | X | X | X | X | 7 | 250.9 | 60 |
| 16.02.2000 | 47 | 108 | X | X | X | 6 | 266.5 | 60 | X | X | X |
| 25.02.2000 | 56 | 116 | 5 | 303.3 | 60 | X | X | X | 8 | 33.3 | 60 |
| **Total** | | | **5** | **-** | **300** | **6** | **-** | **360** | **8** | **-** | **480** |

## Appendix 4. Prices of inputs and outputs

| Sl. No. | Particular | Price (Rs.) | |
|---|---|---|---|
| | | 1998-99 | 1999-2000 |
| **I INPUTS** | | | |
| 1 | Seeds | 20 $kg^{-1}$ | 20 $kg^{-1}$ |
| **2** | **Fertilizers** | | |
| | Urea | 3.52 $kg^{-1}$ | 4.0 $kg^{-1}$ |
| | Single super phosphate | 2.77 $kg^{-1}$ | 2.85 $kg^{-1}$ |
| | Muriate of potash | 3.65 $kg^{-1}$ | 3.70 $kg^{-1}$ |
| | Zinc sulphate | 30 $kg^{-1}$ | 30 $kg^{-1}$ |
| **3.** | **Plant protection chemicals** | | |
| | Mancozeb | 260 $kg^{-1}$ | 260 $kg^{-1}$ |
| | Ridomil | 1350$kg^{-1}$ | 1350$kg^{-1}$ |
| | Endosulfan | 200 $kg^{-1}$ | 200 $kg^{-1}$ |
| | Monocrotophos | 320 $kg^{-1}$ | 320 $kg^{-1}$ |
| | Furadon | 60 $kg^{-1}$ | 60 $kg^{-1}$ |
| | Malathian dust | 25 $kg^{-1}$ | 25 $kg^{-1}$ |
| | Weedicides –Atrataf | 139 $kg^{-1}$ | 139 $kg^{-1}$ |
| **4.** | **Labour wages** | | |
| | Men | 40 $day^{-1}$ | 40 $day^{-1}$ |
| | Women | 40 $day^{-1}$ | 40 $day^{-1}$ |
| | Bullock pair | 125 $day^{-1}$ | 125 $day^{-1}$ |
| | Tractor- cultivator/ transportation | 250 $hr^{-1}$ | 250 $hr^{-1}$ |
| 5 | Irrigation charges | 75 $irrigation^{-1}$ $ha^{-1}$ | 75 $irrigation^{-1}$ $ha^{-1}$ |
| **II. OUTPUTS (PRODUCE)** | | | |
| | Grain | 500 $q^{-1}$ | 500 $q^{-1}$ |
| | Stover | 300 $t^{-1}$ | 300 $t^{-1}$ |

- Prices of inputs and outputs are taken from Main Research Station, University of Agricultural Sciences, Dharwad

## Appendix 5. Plant height (cm) of maize varieties at different growth stages as influenced by planting dates

| Growth stages | 30 DAS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1998-99 | | | | | 1999-2000 | | | | |
| Treatments | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| $V_1$ | 27.00 | 24.00 | 22.00 | 19.00 | **23.00** | 21.67 | 17.67 | 17.00 | 15.67 | **18.00** |
| $V_2$ | 27.67 | 25.00 | 23.00 | 18.83 | **23.66** | 22.67 | 19.67 | 18.00 | 15.67 | **19.08** |
| $V_3$ | 27.67 | 25.00 | 22.00 | 18.83 | **23.38** | 22.67 | 20.00 | 17.00 | 15.67 | **18.83** |
| $V_4$ | 27.00 | 24.00 | 20.00 | 16.83 | **21.96** | 22.60 | 20.00 | 16.33 | 15.67 | **18.42** |
| $V_5$ | 21.33 | 18.00 | 18.00 | 15.67 | **18.25** | 22.00 | 19.67 | 15.67 | 14.83 | **16.54** |
| **Mean** | **26.13** | **23.10** | **21.00** | **17.83** | **22.05** | **21.53** | **19.27** | **16.93** | **15.50** | **18.17** |
| **Comparing means of** | **SEm ±** | | | **CD (0.05)** | | **SEm ±** | | | **CD (0.05)** | |
| **Planting dates** | 0.244 | | | 0.844 | | 0.345 | | | 1.193 | |
| **Varieties** | 0.182 | | | 0.506 | | 0.192 | | | 0.532 | |
| **Planting dates x Varieties** | 0.365 | | | 1.012 | | 0.384 | | | 1.064 | |
| **Growth stages** | **Anthesis** | | | | | | | | | |
| **Treatments** | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| $V_1$ | 228.00 | 228.00 | 229.67 | 224.67 | **227.58** | 200.67 | 200.33 | 202.26 | 196.67 | **199.98** |
| $V_2$ | 228.00 | 232.00 | 231.00 | 227.67 | **229.67** | 198.00 | 200.33 | 203.59 | 196.67 | **199.65** |
| $V_3$ | 230.00 | 232.00 | 233.67 | 229.33 | **231.33** | 196.67 | 198.00 | 202.59 | 197.00 | **198.57** |
| $V_4$ | 224.33 | 218.33 | 222.00 | 242.00 | **226.67** | 184.00 | 183.00 | 190.33 | 190.43 | **186.94** |
| $V_5$ | 184.67 | 185.00 | 182.67 | 175.33 | **181.92** | 166.67 | 170.00 | 176.67 | 169.33 | **170.67** |
| **Mean** | **219.00** | **219.13** | **219.80** | **219.80** | **219.43** | **189.20** | **190.33** | **195.09** | **190.02** | **191.16** |
| **Comparing means of** | **SEm ±** | | | **CD (0.05)** | | **SEm ±** | | | **CD (0.05)** | |
| **Planting dates** | 1.582 | | | 5.475 | | 0.493 | | | 1.705 | |
| **Varieties** | 1.348 | | | 3.737 | | 0.519 | | | 1.437 | |
| **Planting dates x Varieties** | 2.696 | | | 7.674 | | 1.037 | | | 2.875 | |

| Growth stages | Physiological maturity | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| $V_1$ | 228.00 | 228.00 | 229.67 | 224.67 | **227.58** | 200.67 | 200.33 | 202.26 | 196.67 | **199.98** |
| $V_2$ | 228.00 | 232.00 | 231.00 | 227.67 | **229.67** | 198.00 | 200.33 | 203.59 | 196.67 | **199.65** |
| $V_3$ | 230.00 | 232.00 | 233.67 | 229.33 | **231.33** | 196.67 | 198.00 | 202.59 | 197.00 | **198.57** |
| $V_4$ | 224.33 | 218.33 | 222.00 | 242.00 | **226.67** | 184.00 | 183.00 | 190.33 | 190.43 | **186.94** |
| $V_5$ | 184.67 | 185.00 | 182.67 | 175.33 | **181.92** | 166.67 | 170.00 | 176.67 | 169.33 | **170.67** |
| **Mean** | **219.00** | **219.13** | **219.80** | **219.80** | **219.43** | **189.20** | **190.33** | **195.09** | **190.02** | **191.16** |
| | | | | | | | | | | |
| | **1998-99** | | | | | **1999-2000** | | | | |
| **Comparing means of** | **SEm ±** | | | **CD (0.05)** | | **SEm ±** | | | **CD (0.05)** | |
| **Planting dates** | 1.582 | | | 5.475 | | 0.493 | | | 1.705 | |
| **Varieties** | 1.348 | | | 3.737 | | 0.519 | | | 1.437 | |
| **Planting dates x Varieties** | 2.696 | | | 7.674 | | 1.037 | | | 2.875 | |

DAS: Days after sowing
Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.
Varieties (V) : V1 = Deccan 103 ; V2 = DMH – 1 ; V3 = DMH – 2 ; V4 = Prabha (G-57) ; V5 = Renuka (G-25).

## Appendix 6. Number of leaves of maize varieties at different growth stages as influenced by planting dates

| Growth stages | 30 DAS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1998-99 | | | | | 1999-2000 | | | | |
| Treatments | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| $V_1$ | 9.80 | 8.90 | 8.80 | 8.20 | **8.93** | 9.70 | 8.70 | 8.20 | 7.90 | **8.63** |
| $V_2$ | 9.80 | 8.90 | 8.80 | 8.20 | **8.93** | 9.70 | 8.70 | 8.20 | 7.90 | **8.63** |
| $V_3$ | 9.80 | 8.90 | 8.80 | 8.20 | **8.93** | 9.30 | 8.70 | 8.20 | 7.90 | **8.53** |
| $V_4$ | 9.80 | 8.90 | 8.80 | 8.20 | **8.93** | 9.70 | 8.70 | 8.00 | 7.90 | **8.58** |
| $V_5$ | 10.00 | 9.00 | 9.00 | 8.80 | **9.20** | 9.80 | 9.00 | 9.00 | 8.90 | **9.18** |
| Mean | **9.84** | **8.92** | **8.84** | **8.32** | **8.98** | **9.64** | **8.76** | **8.32** | **8.10** | **8.71** |
| Comparing means of | SE m | | | CD (0.05) | | SE m | | | CD (0.05) | |
| Planting dates | 0.187 | | | 0.647 | | 0.183 | | | 0.635 | |
| Varieties | 0.025 | | | 0.071 | | 0.065 | | | 0.189 | |
| Planting dates x Varieties | 0.049 | | | 0.143 | | 0.131 | | | 0.377 | |
| Growth stages | Anthesis | | | | | | | | | |
| Treatments | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| $V_1$ | 18.80 | 17.33 | 17.83 | 18.13 | **18.03** | 18.67 | 17.33 | 17.93 | 18.37 | **18.08** |
| $V_2$ | 18.80 | 17.37 | 17.83 | 18.23 | **18.06** | 18.67 | 17.33 | 17.93 | 18.37 | **18.08** |
| $V_3$ | 18.70 | 17.33 | 17.83 | 18.20 | **18.02** | 18.83 | 17.33 | 17.93 | 18.33 | **18.11** |
| $V_4$ | 18.80 | 17.37 | 17.83 | 18.23 | **18.06** | 18.67 | 17.38 | 17.93 | 18.33 | **18.08** |
| $V_5$ | 13.80 | 13.23 | 13.80 | 12.65 | **13.37** | 13.23 | 13.38 | 13.60 | 12.37 | **13.15** |
| Mean | **17.78** | **16.53** | **17.03** | **17.09** | **17.11** | **17.61** | **16.55** | **17.07** | **17.15** | **17.09** |
| Comparing means of | SEm ± | | | CD (0.05) | | SEm ± | | | CD (0.05) | |
| Planting dates | 0.188 | | | 0.650 | | 0.121 | | | 0.420 | |
| Varieties | 0.098 | | | 0.282 | | 0.104 | | | 0.300 | |
| Planting dates x Varieties | 0.195 | | | 0.563 | | 0.208 | | | 0.600 | |
| Growth stages | Physiological maturity | | | | | | | | | |
| Treatments | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| $V_1$ | 18.80 | 17.33 | 17.83 | 18.13 | **18.03** | 18.67 | 17.33 | 17.93 | 18.37 | **18.08** |
| $V_2$ | 18.80 | 17.37 | 17.83 | 18.23 | **18.06** | 18.67 | 17.33 | 17.93 | 18.37 | **18.08** |
| $V_3$ | 18.70 | 17.33 | 17.83 | 18.20 | **18.02** | 18.83 | 17.33 | 17.93 | 18.33 | **18.11** |
| $V_4$ | 18.80 | 17.37 | 17.83 | 18.23 | **18.06** | 18.67 | 17.38 | 17.93 | 18.33 | **18.08** |
| $V_5$ | 13.80 | 13.23 | 13.80 | 12.65 | **13.37** | 13.23 | 13.38 | 13.60 | 12.37 | **13.15** |
| Mean | **17.78** | **16.53** | **17.03** | **17.09** | **17.11** | **17.61** | **16.55** | **17.07** | **17.15** | **17.09** |

| | 1998-99 | | 1999-2000 | |
|---|---|---|---|---|
| Comparing means of | SEm ± | CD (0.05) | SEm ± | CD (0.05) |
| Planting dates | 0.188 | 0.650 | 0.121 | 0.420 |
| Varieties | 0.098 | 0.282 | 0.104 | 0.300 |
| Planting dates x Varieties | 0.195 | 0.563 | 0.208 | 0.600 |

DAS: Days after sowing
Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.
Varieties (V) : V1 = Deccan 103 ; V2 = DMH – 1 ; V3 = DMH – 2 ; V4 = Prabha (G-57) ; V5 = Renuka (G-25).

## Appendix 7. Leaf area index of maize varieties at different growth stages as influenced by planting dates

| Growth stages | 30 DAS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1998-99 | | | | | 1999-2000 | | | | |
| Treatments | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| $V_1$ | 0.77 | 0.72 | 0.53 | 0.47 | **0.62** | 0.76 | 0.69 | 0.46 | 0.48 | **0.60** |
| $V_2$ | 0.77 | 0.72 | 0.53 | 0.47 | **0.62** | 0.76 | 0.69 | 0.46 | 0.48 | **0.60** |
| $V_3$ | 0.78 | 0.72 | 0.53 | 0.50 | **0.63** | 0.76 | 0.70 | 0.46 | 0.48 | **0.60** |
| $V_4$ | 0.77 | 0.72 | 0.53 | 0.47 | **0.62** | 0.76 | 0.69 | 0.46 | 0.48 | **0.60** |
| $V_5$ | 0.86 | 0.76 | 0.56 | 0.53 | **0.68** | 0.79 | 0.75 | 0.48 | 0.62 | **0.66** |
| **Mean** | **0.79** | **0.73** | **0.54** | **0.49** | **0.64** | **0.77** | **0.70** | **0.46** | **0.51** | **0.61** |
| **Comparing means of** | **SEm ±** | | | **CD (0.05)** | | **SEm ±** | | | **CD (0.05)** | |
| **Planting dates** | 0.002 | | | 0.007 | | 0.003 | | | 0.011 | |
| **Varieties** | 0.001 | | | 0.001 | | 0.001 | | | 0.002 | |
| **Planting dates x Varieties** | 0.001 | | | 0.003 | | 0.002 | | | 0.005 | |
| **Growth stages** | **Anthesis** | | | | | | | | | |
| **Treatments** | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| $V_1$ | 3.58 | 3.19 | 3.40 | 3.37 | **3.39** | 3.55 | 3.42 | 3.45 | 3.31 | **3.43** |
| $V_2$ | 3.58 | 3.19 | 3.40 | 3.37 | **3.39** | 3.55 | 3.42 | 3.45 | 3.31 | **3.43** |
| $V_3$ | 3.58 | 3.19 | 3.40 | 3.10 | **3.32** | 3.55 | 3.42 | 3.45 | 3.31 | **3.43** |
| $V_4$ | 3.58 | 3.19 | 3.40 | 3.37 | **3.39** | 3.55 | 3.42 | 3.45 | 3.31 | **3.43** |
| $V_5$ | 1.63 | 1.47 | 1.27 | 1.49 | **1.47** | 1.47 | 1.46 | 1.51 | 1.34 | **1.45** |
| **Mean** | **3.19** | **2.85** | **2.97** | **2.94** | **2.99** | **3.13** | **3.03** | **3.06** | **2.92** | **3.04** |
| **Comparing means of** | **SEm ±** | | | **CD (0.05)** | | **SEm ±** | | | **CD (0.05)** | |
| **Planting dates** | 0.001 | | | 0.004 | | 0.001 | | | 0.003 | |
| **Varieties** | 0.005 | | | 0.013 | | 0.005 | | | 0.014 | |
| **Planting dates x Varieties** | 0.009 | | | 0.026 | | 0.010 | | | 0.029 | |
| **Growth stages** | **Physiological maturity** | | | | | | | | | |
| **Treatments** | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| $V_1$ | 1.38 | 1.31 | 1.42 | 1.38 | **1.37** | 1.41 | 1.39 | 1.37 | 1.39 | **1.39** |
| $V_2$ | 1.38 | 1.31 | 1.42 | 1.38 | **1.37** | 1.41 | 1.39 | 1.37 | 1.39 | **1.39** |
| $V_3$ | 1.38 | 1.31 | 1.38 | 1.35 | **1.36** | 1.40 | 1.39 | 1.42 | 1.34 | **1.39** |
| $V_4$ | 1.39 | 1.33 | 1.38 | 1.35 | **1.36** | 1.43 | 1.41 | 1.42 | 1.34 | **1.40** |
| $V_5$ | 0.67 | 0.58 | 0.51 | 0.59 | **0.59** | 0.60 | 0.57 | 0.64 | 0.53 | **0.59** |
| **Mean** | **1.24** | **1.17** | **1.22** | **1.21** | **1.21** | **1.25** | **1.23** | **1.24** | **1.20** | **1.23** |

| | 1998-99 | | 1999-2000 | |
|---|---|---|---|---|
| **Comparing means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Planting dates** | 0.004 | 0.014 | 0.032 | 0.110 |
| **Varieties** | 0.006 | 0.018 | 0.038 | 0.109 |
| **Planting dates x Varieties** | 0.013 | 0.037 | 0.076 | 0.218 |

DAS: Days after sowing

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.
Varieties (V) : V1 = Deccan 103 ; V2 = DMH – 1 ; V3 = DMH – 2 ; V4 = Prabha (G-57) ; V5 = Renuka (G-25).

**Appendix 8. Total dry matter (g plant[1]) of maize varieties at different growth stages as influenced by planting dates**

| Growth stages | | | | | 30 DAS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | | | 1998-99 | | | | 1999-2000 | | | |
| Treatments | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| V1 | 8.73 | 6.83 | 7.93 | 4.80 | **7.07** | 8.50 | 5.60 | 6.67 | 4.90 | **6.42** |
| V2 | 8.80 | 6.90 | 7.97 | 4.80 | **7.12** | 8.57 | 5.60 | 6.70 | 5.00 | **6.47** |
| V3 | 8.87 | 6.90 | 7.97 | 4.80 | **7.14** | 8.67 | 5.60 | 6.70 | 5.00 | **6.49** |
| V4 | 8.73 | 7.17 | 7.93 | 4.80 | **7.16** | 8.53 | 5.60 | 6.67 | 4.90 | **6.43** |
| V5 | 10.20 | 7.77 | 8.47 | 8.57 | **8.75** | 10.20 | 6.77 | 7.27 | 6.17 | **7.60** |
| Mean | **9.07** | **7.11** | **8.05** | **5.55** | **7.45** | **8.89** | **5.83** | **6.80** | **5.19** | **6.68** |

| Comparing means of | SEm ± | CD (0.05) | SEm ± | CD (0.05) |
|---|---|---|---|---|
| Planting dates | 0.033 | 0.115 | 0.017 | 0.058 |
| Varieties | 0.037 | 0.106 | 0.009 | 0.025 |
| Planting dates x Varieties | 0.074 | 0.212 | 0.018 | 0.051 |

| Growth stages | | | | | Anthesis | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| V1 | 114.83 | 102.03 | 110.60 | 110.20 | **109.42** | 114.27 | 107.57 | 111.47 | 108.73 | **110.51** |
| V2 | 114.93 | 102.10 | 110.73 | 110.27 | **109.51** | 114.37 | 107.70 | 111.63 | 108.87 | **110.64** |
| V3 | 108.10 | 102.10 | 110.73 | 104.17 | **106.28** | 106.70 | 107.70 | 111.63 | 108.87 | **108.73** |
| V4 | 114.83 | 102.03 | 110.60 | 110.20 | **109.42** | 114.27 | 107.57 | 111.47 | 108.73 | **110.51** |
| V5 | 59.00 | 49.00 | 44.33 | 52.60 | **51.23** | 52.50 | 52.20 | 55.30 | 44.63 | **51.16** |
| Mean | **102.34** | **91.45** | **97.40** | **97.49** | **97.17** | **100.42** | **96.55** | **100.30** | **95.97** | **98.31** |

| Comparing means of | SE m | CD (0.05) | SE m | CD (0.05) |
|---|---|---|---|---|
| Planting dates | 0.295 | 1.109 | 0.025 | 0.087 |
| Varieties | 0.354 | 1.021 | 0.137 | 0.396 |
| Planting dates x Varieties | 0.707 | 2.042 | 0.275 | 0.793 |

| Growth stages | | | | | Physiological maturity | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean | $D_1$ | $D_2$ | $D_3$ | $D_4$ | Mean |
| V1 | 269.00 | 256.57 | 253.67 | 253.87 | **258.28** | 270.33 | 269.57 | 285.03 | 270.97 | **273.98** |
| V2 | 285.14 | 272.87 | 268.07 | 268.80 | **273.72** | 286.43 | 284.06 | 284.73 | 286.30 | **285.38** |
| V3 | 287.63 | 281.04 | 282.10 | 266.57 | **279.34** | 290.30 | 297.57 | 295.54 | 299.00 | **295.60** |
| V4 | 259.87 | 248.23 | 248.10 | 259.07 | **253.82** | 261.40 | 259.57 | 259.76 | 264.37 | **261.28** |
| V5 | 170.27 | 142.73 | 144.89 | 151.70 | **152.40** | 154.47 | 154.93 | 160.86 | 139.77 | **152.51** |
| Mean | **254.38** | **240.29** | **239.37** | **240.00** | **243.51** | **252.59** | **253.14** | **257.18** | **252.08** | **253.75** |

| | 1998-99 | | 1999-2000 | |
|---|---|---|---|---|
| Comparing means of | SEm ± | CD (0.05) | SEm ± | CD (0.05) |
| Planting dates | 0.054 | 0.188 | 0.187 | 0.647 |
| Varieties | 0.302 | 0.872 | 0.351 | 1.014 |
| Planting dates x Varieties | 0.604 | 1.745 | 0.703 | 2.029 |

DAS: Days after sowing

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : V1 = Deccan 103 ; V2 = DMH – 1 ; V3 = DMH – 2 ; V4 = Prabha (G-57) ; V5 = Renuka (G-25).

**Appendix 9. Dry matter production (g plant[1]) of maize varieties in different plant parts at physiological maturity**

**as influenced by planting dates**

| Growth stages | | | | | | Leaf dry matter | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | | | **1998-99** | | | | **1999-2000** | | | |
| **Treatments** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** |
| **$V_1$** | 42.13 | 36.77 | 41.67 | 42.57 | **40.79** | 42.83 | 41.10 | 42.63 | 40.70 | **41.82** |
| **$V_2$** | 42.17 | 36.77 | 41.67 | 42.57 | **40.80** | 42.83 | 41.10 | 42.63 | 40.70 | **41.82** |
| **$V_3$** | 39.03 | 36.57 | 41.00 | 37.87 | **38.62** | 38.63 | 40.80 | 42.47 | 40.50 | **40.60** |
| **$V_4$** | 42.17 | 36.73 | 41.57 | 42.47 | **40.74** | 42.83 | 41.10 | 42.63 | 40.60 | **41.79** |
| **$V_5$** | 15.47 | 13.37 | 11.50 | 13.93 | **13.57** | 13.57 | 13.77 | 13.93 | 12.97 | **13.56** |
| **Mean** | **36.19** | **32.04** | **35.48** | **35.88** | **34.90** | **36.14** | **35.57** | **36.86** | **35.09** | **35.92** |

| Comparing means of | SEm ± | CD (0.05) | SEm ± | CD (0.05) |
|---|---|---|---|---|
| **Planting dates** | 0.019 | 0.065 | 0.014 | 0.049 |
| **Varieties** | 0.064 | 0.184 | 0.067 | 0.195 |
| **Planting dates x Varieties** | 0.128 | 0.368 | 0.135 | 0.389 |

| Growth stages | | | | | | Stem dry matter | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** |
| **$V_1$** | 60.77 | 56.77 | 59.97 | 58.20 | **58.93** | 60.97 | 58.47 | 59.50 | 59.10 | **59.51** |
| **$V_2$** | 60.77 | 56.83 | 60.00 | 58.20 | **58.95** | 60.80 | 56.73 | 59.20 | 57.50 | **58.56** |
| **$V_3$** | 58.80 | 54.87 | 59.50 | 55.73 | **57.23** | 56.80 | 54.40 | 57.12 | 52.70 | **55.26** |
| **$V_4$** | 60.77 | 56.73 | 59.90 | 58.10 | **58.88** | 60.97 | 57.90 | 59.50 | 59.10 | **59.37** |
| **$V_5$** | 42.30 | 35.63 | 34.13 | 38.83 | **37.72** | 37.60 | 38.33 | 41.03 | 31.53 | **37.12** |
| **Mean** | **56.68** | **52.17** | **54.70** | **53.81** | **54.34** | **55.43** | **53.17** | **55.27** | **51.99** | **53.96** |

| Comparing means of | SEm ± | CD (0.05) | SEm ± | CD (0.05) |
|---|---|---|---|---|
| **Planting dates** | 0.028 | 0.097 | 0.027 | 0.093 |
| **Varieties** | 0.049 | 0.141 | 0.045 | 0.129 |
| **Planting dates x Varieties** | 0.098 | 0.282 | 0.089 | 0.257 |

| Growth stages | | | | | | Cob dry matter | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** | **$D_1$** | **$D_2$** | **$D_3$** | **$D_4$** | **Mean** |
| **$V_1$** | 166.10 | 163.03 | 152.03 | 153.10 | **158.57** | 166.53 | 169.60 | 182.90 | 171.17 | **172.55** |
| **$V_2$** | 182.20 | 179.27 | 166.40 | 168.03 | **173.98** | 182.80 | 186.23 | 182.90 | 188.10 | **185.01** |
| **$V_3$** | 189.80 | 189.60 | 181.60 | 172.97 | **183.49** | 194.87 | 202.37 | 195.57 | 205.80 | **199.65** |
| **$V_4$** | 156.93 | 154.77 | 146.63 | 158.50 | **154.21** | 157.60 | 160.57 | 157.63 | 164.67 | **160.12** |
| **$V_5$** | 112.50 | 93.73 | 99.26 | 98.94 | **101.11** | 103.30 | 102.83 | 105.90 | 95.27 | **101.83** |
| **Mean** | **161.51** | **156.08** | **149.18** | **150.31** | **154.27** | **161.02** | **164.32** | **164.98** | **165.00** | **163.83** |

| | **1998-99** | | **1999-2000** | |
|---|---|---|---|---|
| **Comparing means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Planting dates** | 1.050 | 3.634 | 0.081 | 0.268 |
| **Varieties** | 1.210 | 3.495 | 0.294 | 0.849 |
| **Planting dates x Varieties** | 2.420 | 6.989 | 0.588 | 1.693 |

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : V1 = Deccan 103 ; V2 = DMH – 1 ; V3 = DMH – 2 ; V4 = Prabha (G-57) ; V5 = Renuka (G-25).

**Appendix 10. Plant height (cm) of maize at 30 and 60 DAS as influenced by irrigation scheduling, plant density and nitrogen levels**

| Growth stages | | | | | | | | 30 DAS | | | | | | | 60 DAS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | | | 1998-1999 | | | | 1999-2000 | | | | 1998-1999 | | | | 1999-2000 | |
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 29.40 | 31.21 | 32.11 | **30.91** | 26.33 | 28.23 | 29.03 | **27.86** | 145.00 | 154.93 | 163.67 | **154.53** | 141.00 | 152.00 | 156.00 | **149.67** |
| $I_1N_2$ | 29.40 | 31.22 | 32.11 | **30.91** | 26.57 | 28.40 | 29.27 | **28.08** | 149.00 | 160.30 | 167.33 | **158.88** | 147.00 | 158.00 | 162.00 | **155.67** |
| $I_1N_3$ | 29.40 | 31.20 | 32.03 | **30.88** | 26.57 | 28.43 | 29.20 | **28.07** | 150.00 | 164.67 | 169.00 | **161.22** | 153.00 | 161.33 | 164.00 | **159.44** |
| $I_1N_4$ | 29.40 | 31.15 | 32.03 | **30.86** | 26.57 | 28.43 | 29.17 | **28.06** | 161.50 | 165.00 | 170.00 | **165.50** | 153.33 | 160.67 | 163.67 | **159.22** |
| **Mean** | **29.40** | **31.20** | **32.07** | **30.89** | **26.51** | **28.37** | **29.17** | **28.02** | **151.38** | **161.23** | **167.50** | **160.03** | **148.58** | **158.00** | **161.42** | **156.00** |
| $I_2N_1$ | 30.17 | 33.53 | 34.00 | **32.57** | 26.97 | 30.83 | 32.10 | **29.97** | 150.33 | 158.33 | 162.37 | **157.01** | 146.00 | 153.33 | 157.00 | **152.11** |
| $I_2N_2$ | 31.37 | 34.03 | 34.87 | **33.42** | 28.30 | 32.13 | 33.40 | **31.28** | 159.00 | 165.00 | 169.33 | **164.44** | 155.00 | 161.67 | 165.00 | **160.56** |
| $I_2N_3$ | 31.97 | 34.60 | 36.30 | **34.29** | 28.67 | 32.50 | 34.73 | **31.97** | 161.67 | 169.00 | 173.00 | **167.89** | 162.00 | 165.33 | 169.00 | **165.44** |
| $I_2N_4$ | 31.97 | 34.70 | 36.43 | **34.37** | 28.77 | 32.90 | 35.13 | **32.27** | 162.33 | 170.83 | 174.00 | **169.05** | 163.33 | 168.00 | 172.00 | **167.78** |
| **Mean** | **31.37** | **34.22** | **35.40** | **33.66** | **28.18** | **32.09** | **33.84** | **31.37** | **158.33** | **165.79** | **169.68** | **164.60** | **156.58** | **162.08** | **165.75** | **161.47** |
| $I_3N_1$ | 30.00 | 33.97 | 34.13 | **32.70** | 27.77 | 32.27 | 31.90 | **30.65** | 153.00 | 158.33 | 161.67 | **157.67** | 147.00 | 156.33 | 157.00 | **153.44** |
| $I_3N_2$ | 31.97 | 35.20 | 35.60 | **34.26** | 28.80 | 33.10 | 33.40 | **31.77** | 161.00 | 166.00 | 170.33 | **165.78** | 157.67 | 164.00 | 160.00 | **160.56** |
| $I_3N_3$ | 32.57 | 35.90 | 36.53 | **35.00** | 29.80 | 33.87 | 34.70 | **32.79** | 162.30 | 169.67 | 173.33 | **168.43** | 162.00 | 168.00 | 171.00 | **167.00** |
| $I_3N_4$ | 32.97 | 36.27 | 36.73 | **35.32** | 30.63 | 34.13 | 35.40 | **33.39** | 164.00 | 170.67 | 174.33 | **169.67** | 163.33 | 171.00 | 173.00 | **169.11** |
| **Mean** | **31.88** | **35.34** | **35.75** | **34.32** | **29.25** | **33.34** | **33.85** | **32.15** | **160.08** | **166.17** | **169.92** | **165.39** | **157.50** | **164.83** | **165.25** | **162.53** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 29.86 | 32.90 | 33.41 | **32.06** | 27.02 | 30.44 | 31.01 | **29.49** | 149.44 | 157.20 | 162.57 | **156.40** | 144.67 | 153.89 | 156.67 | **151.74** |
| **N2** | 30.91 | 33.48 | 34.19 | **32.86** | 27.89 | 31.21 | 32.02 | **30.37** | 156.33 | 163.77 | 169.00 | **163.03** | 153.22 | 161.22 | 162.33 | **158.93** |
| **N3** | 31.31 | 33.90 | 34.95 | **33.39** | 28.35 | 31.60 | 32.88 | **30.94** | 157.99 | 167.78 | 171.78 | **165.85** | 159.00 | 164.89 | 168.00 | **163.96** |
| **N4** | 31.45 | 34.04 | 35.06 | **33.52** | 28.66 | 31.82 | 33.23 | **31.24** | 162.61 | 168.83 | 172.78 | **168.07** | 160.00 | 166.56 | 169.56 | **165.37** |
| **Mean** | **30.88** | **33.58** | **34.41** | **32.96** | **27.98** | **31.27** | **32.29** | **30.51** | **156.59** | **164.39** | **169.03** | **163.34** | **154.22** | **161.64** | **164.14** | **160.00** |

| | | | | 30 DAS | | | 60 DAS | |
|---|---|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Irrigation (I)** | 0.185 | 0.725 | 0.126 | 0.496 | 0.082 | 0.320 | 0.124 | 0.488 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Plant Density (P)** | 0.045 | 0.124 | 0.083 | 0.230 | 0.156 | 0.434 | 0.113 | 0.312 |
| **Nitrogen levels (N)** | 0.052 | 0.143 | 0.096 | 0.265 | 0.181 | 0.354 | 0.130 | 0.360 |
| **I X P** | 0.078 | 0.215 | 0.143 | 0.397 | 0.271 | 0.751 | 0.195 | 0.540 |
| **I X N** | 0.090 | 0.248 | 0.166 | 0.459 | 0.313 | 0.867 | 0.225 | 0.623 |
| **P X N** | 0.090 | 0.248 | 0.166 | 0.459 | 0.313 | 0.867 | 0.225 | 0.623 |
| **I X P X N** | 0.155 | 0.430 | 0.287 | 0.795 | 0.542 | 1.502 | 0.390 | 1.080 |

DAS: Days after sowing

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants $ha^{-1}$; $P_2$ = 83333 Plants $ha^{-1}$; $P_3$ = 111111 Plants $ha^{-1}$.

Nitrogen levels (N) : $N_1$ = 75 Kg $ha^{-1}$; $N_2$ = 150 Kg $ha^{-1}$; $N_3$ = 225 Kg $ha^{-1}$; $N_4$ = 300 Kg $ha^{-1}$.

**Appendix 11. Plant height (cm) of maize at 90 DAS and physiological maturity as influenced by irrigation scheduling, plant density and nitrogen levels**

| Growth stages | | | | 90 DAS | | | | | | | | Physiological maturity | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1998-1999 | | | | 1999-2000 | | | | 1998-1999 | | | | 1999-2000 | | | |
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 205.00 | 214.67 | 221.67 | **213.78** | 191.00 | 202.00 | 206.00 | **199.67** | 205.00 | 214.67 | 221.67 | **213.78** | 191.00 | 202.00 | 206.00 | **199.67** |
| $I_1N_2$ | 209.00 | 220.00 | 227.33 | **218.78** | 197.00 | 208.00 | 212.00 | **205.67** | 209.00 | 220.00 | 227.33 | **218.78** | 197.00 | 208.00 | 212.00 | **205.67** |
| $I_1N_3$ | 210.00 | 224.67 | 229.00 | **221.22** | 203.00 | 211.33 | 214.00 | **209.44** | 210.00 | 224.67 | 229.00 | **221.22** | 203.00 | 211.33 | 214.00 | **209.44** |
| $I_1N_4$ | 211.50 | 225.00 | 230.00 | **222.17** | 203.33 | 210.67 | 213.33 | **209.11** | 211.50 | 225.00 | 230.00 | **222.17** | 203.33 | 210.67 | 213.33 | **209.11** |
| **Mean** | **208.88** | **221.09** | **227.00** | **218.99** | **198.58** | **208.00** | **211.33** | **205.97** | **208.88** | **221.09** | **227.00** | **218.99** | **198.58** | **208.00** | **211.33** | **205.97** |
| $I_2N_1$ | 210.33 | 218.00 | 222.37 | **216.90** | 196.20 | 203.33 | 207.00 | **202.18** | 210.33 | 218.00 | 222.37 | **216.90** | 196.20 | 203.33 | 207.00 | **202.18** |
| $I_2N_2$ | 219.00 | 225.00 | 229.33 | **224.44** | 205.10 | 211.67 | 215.00 | **210.59** | 219.00 | 225.00 | 229.33 | **224.44** | 205.10 | 211.67 | 215.00 | **210.59** |
| $I_2N_3$ | 221.67 | 229.00 | 233.00 | **227.89** | 212.10 | 215.33 | 219.00 | **215.48** | 221.67 | 229.00 | 233.00 | **227.89** | 212.10 | 215.33 | 219.00 | **215.48** |
| $I_2N_4$ | 222.33 | 230.83 | 234.00 | **229.05** | 213.20 | 218.00 | 222.00 | **217.73** | 222.33 | 230.83 | 234.00 | **229.05** | 213.20 | 218.00 | 222.00 | **217.73** |
| **Mean** | **218.33** | **225.71** | **229.68** | **224.57** | **206.65** | **212.08** | **215.75** | **211.49** | **218.33** | **225.71** | **229.68** | **224.57** | **206.65** | **212.08** | **215.75** | **211.49** |
| $I_3N_1$ | 213.00 | 218.33 | 221.66 | **217.66** | 197.00 | 206.33 | 207.00 | **203.44** | 213.00 | 218.33 | 221.66 | **217.66** | 197.00 | 206.33 | 207.00 | **203.44** |
| $I_3N_2$ | 221.00 | 226.00 | 230.33 | **225.78** | 208.00 | 214.00 | 216.00 | **212.67** | 221.00 | 226.00 | 230.33 | **225.78** | 208.00 | 214.00 | 216.00 | **212.67** |
| $I_3N_3$ | 222.30 | 230.00 | 233.33 | **228.54** | 212.17 | 218.00 | 221.00 | **217.06** | 222.30 | 230.00 | 233.33 | **228.54** | 212.17 | 218.00 | 221.00 | **217.06** |
| $I_3N_4$ | 224.00 | 230.67 | 234.50 | **229.72** | 213.40 | 221.00 | 223.10 | **219.17** | 224.00 | 230.67 | 234.50 | **229.72** | 213.40 | 221.00 | 223.10 | **219.17** |
| **Mean** | **220.08** | **226.25** | **229.96** | **225.43** | **207.64** | **214.83** | **216.78** | **213.08** | **220.08** | **226.25** | **229.96** | **225.43** | **207.64** | **214.83** | **216.78** | **213.08** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 209.44 | 217.00 | 221.90 | **216.11** | 194.73 | 203.89 | 206.67 | **201.76** | 209.44 | 217.00 | 221.90 | **216.11** | 194.73 | 203.89 | 206.67 | **201.76** |
| **N2** | 216.33 | 223.67 | 229.00 | **223.00** | 203.37 | 211.22 | 214.33 | **209.64** | 216.33 | 223.67 | 229.00 | **223.00** | 203.37 | 211.22 | 214.33 | **209.64** |
| **N3** | 217.99 | 227.89 | 231.78 | **225.89** | 209.09 | 214.89 | 218.00 | **213.99** | 217.99 | 227.89 | 231.78 | **225.89** | 209.09 | 214.89 | 218.00 | **213.99** |
| **N4** | 219.28 | 228.83 | 232.83 | **226.98** | 209.98 | 216.56 | 219.48 | **215.34** | 219.28 | 228.83 | 232.83 | **226.98** | 209.98 | 216.56 | 219.48 | **215.34** |
| **Mean** | **215.76** | **224.35** | **228.88** | **223.00** | **204.29** | **211.64** | **214.62** | **210.18** | **215.76** | **224.35** | **228.88** | **223.00** | **204.29** | **211.64** | **214.62** | **210.18** |

| | **30 DAS** | | | | **60 DAS** | | | |
|---|---|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** | **SEm ±** | **CD (0.05)** |
| **Irrigation (I)** | 0.040 | 0.111 | 0.124 | 0.485 | 0.040 | 0.111 | 0.124 | 0.485 |
| **Plant Density (P)** | 0.113 | 0.314 | 0.111 | 0.313 | 0.113 | 0.314 | 0.111 | 0.313 |
| **Nitrogen levels (N)** | 0.131 | 0.363 | 0.129 | 0.356 | 0.131 | 0.363 | 0.129 | 0.356 |
| **I X P** | 0.196 | 0.544 | 0.193 | 0.534 | 0.196 | 0.544 | 0.193 | 0.534 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **I X N** | 0.227 | 0.628 | 0.223 | 0.617 | 0.227 | 0.628 | 0.223 | 0.617 |
| **P X N** | 0.227 | 0.628 | 0.223 | 0.617 | 0.227 | 0.628 | 0.223 | 0.617 |
| **I X P X N** | 0.392 | 1.087 | 0.386 | 1.069 | 0.392 | 1.087 | 0.386 | 1.069 |

DAS: Days after sowing

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants $ha^{-1}$; $P_2$ = 83333 Plants $ha^{-1}$; $P_3$ = 111111 Plants $ha^{-1}$.

Nitrogen levels (N) : $N_1$ = 75 Kg $ha^{-1}$; $N_2$ = 150 Kg $ha^{-1}$; $N_3$ = 225 Kg $ha^{-1}$; $N_4$ = 300 Kg $ha^{-1}$.

**Appendix 12. Leaf area index of maize at 30, 60 and 90 DAS as influenced by irrigation scheduling, plant density and nitrogen levels**

| Growth stages | 30 DAS | | | | | | | | 60 DAS | | | | | | | | 90 DAS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1998-1999 | | | | 1999-2000 | | | | 1998-1999 | | | | 1999-2000 | | | | 1998-1999 | | | | 1999-2000 | | | |
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 0.63 | 0.95 | 1.21 | **0.93** | 0.60 | 0.84 | 1.02 | **0.82** | 2.80 | 2.85 | 3.83 | **3.16** | 2.66 | 3.17 | 3.55 | **3.13** | 2.76 | 3.55 | 3.76 | **3.36** | 2.28 | 3.03 | 3.23 | **2.85** |
| $I_1N_2$ | 0.64 | 0.96 | 1.17 | **0.92** | 0.60 | 0.84 | 1.01 | **0.82** | 2.81 | 3.59 | 3.95 | **3.45** | 2.59 | 3.37 | 3.89 | **3.28** | 2.77 | 3.56 | 3.81 | **3.38** | 2.58 | 3.03 | 3.51 | **3.04** |
| $I_1N_3$ | 0.65 | 0.97 | 1.18 | **0.93** | 0.61 | 0.85 | 1.02 | **0.83** | 2.83 | 3.46 | 3.76 | **3.35** | 2.72 | 3.36 | 3.92 | **3.33** | 2.77 | 3.21 | 3.39 | **3.12** | 2.46 | 2.78 | 3.42 | **2.89** |
| $I_1N_4$ | 0.65 | 0.97 | 1.18 | **0.93** | 0.61 | 0.85 | 1.02 | **0.83** | 2.81 | 3.42 | 3.69 | **3.31** | 2.71 | 3.32 | 3.91 | **3.31** | 2.76 | 3.16 | 3.30 | **3.07** | 2.44 | 2.73 | 3.13 | **2.77** |
| **Mean** | **0.64** | **0.96** | **1.19** | **0.93** | **0.61** | **0.85** | **1.02** | **0.82** | **2.81** | **3.33** | **3.81** | **3.32** | **2.67** | **3.31** | **3.82** | **3.26** | **2.77** | **3.37** | **3.57** | **3.23** | **2.44** | **2.89** | **3.32** | **2.89** |
| $I_2N_1$ | 0.64 | 0.97 | 1.21 | **0.94** | 0.60 | 0.85 | 1.03 | **0.83** | 3.02 | 3.97 | 4.36 | **3.78** | 2.93 | 3.84 | 4.46 | **3.74** | 2.90 | 3.89 | 4.20 | **3.66** | 2.88 | 3.80 | 4.22 | **3.63** |
| $I_2N_2$ | 0.65 | 0.97 | 1.19 | **0.94** | 0.61 | 0.85 | 1.02 | **0.83** | 3.02 | 4.12 | 4.65 | **3.93** | 2.96 | 4.00 | 4.66 | **3.87** | 2.99 | 4.12 | 4.32 | **3.81** | 2.95 | 4.07 | 4.38 | **3.80** |
| $I_2N_3$ | 0.65 | 0.97 | 1.19 | **0.94** | 0.61 | 0.85 | 1.02 | **0.83** | 3.03 | 4.16 | 4.70 | **3.96** | 2.97 | 4.05 | 4.72 | **3.91** | 3.01 | 4.17 | 4.40 | **3.86** | 2.96 | 4.11 | 4.42 | **3.83** |
| $I_2N_4$ | 0.65 | 0.97 | 1.19 | **0.94** | 0.61 | 0.85 | 1.02 | **0.83** | 3.03 | 4.17 | 4.70 | **3.97** | 2.97 | 4.06 | 4.72 | **3.92** | 3.01 | 4.17 | 4.41 | **3.86** | 2.97 | 4.13 | 4.45 | **3.85** |
| **Mean** | **0.65** | **0.97** | **1.20** | **0.94** | **0.61** | **0.85** | **1.02** | **0.83** | **3.03** | **4.11** | **4.60** | **3.91** | **2.96** | **3.99** | **4.64** | **3.86** | **2.98** | **4.09** | **4.33** | **3.80** | **2.94** | **4.03** | **4.37** | **3.78** |
| $I_3N_1$ | 0.64 | 0.97 | 1.20 | **0.94** | 0.60 | 0.86 | 1.04 | **0.83** | 2.95 | 4.10 | 4.73 | **3.93** | 2.94 | 4.04 | 4.27 | **3.75** | 2.89 | 3.99 | 4.26 | **3.71** | 2.90 | 3.94 | 4.22 | **3.69** |
| $I_3N_2$ | 0.65 | 0.97 | 1.18 | **0.93** | 0.61 | 0.88 | 1.03 | **0.84** | 3.02 | 4.29 | 4.94 | **4.08** | 3.00 | 4.18 | 4.92 | **4.03** | 2.99 | 4.18 | 4.39 | **3.85** | 2.98 | 4.19 | 4.38 | **3.85** |
| $I_3N_3$ | 0.65 | 0.97 | 1.18 | **0.93** | 0.61 | 0.85 | 1.02 | **0.83** | 3.03 | 4.34 | 5.00 | **4.12** | 3.63 | 4.24 | 4.97 | **4.28** | 3.00 | 4.24 | 4.46 | **3.90** | 2.99 | 4.24 | 4.42 | **3.88** |
| $I_3N_4$ | 0.65 | 0.97 | 1.18 | **0.93** | 0.61 | 0.85 | 1.02 | **0.83** | 3.02 | 4.35 | 5.01 | **4.13** | 3.02 | 4.25 | 4.99 | **4.09** | 3.01 | 4.25 | 4.44 | **3.90** | 2.99 | 4.25 | 4.45 | **3.90** |
| **Mean** | **0.65** | **0.97** | **1.19** | **0.93** | **0.61** | **0.86** | **1.03** | **0.83** | **3.01** | **4.27** | **4.92** | **4.07** | **3.15** | **4.18** | **4.79** | **4.04** | **2.97** | **4.17** | **4.39** | **3.84** | **2.97** | **4.16** | **4.37** | **3.83** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 0.64 | 0.96 | 1.21 | **0.94** | 0.60 | 0.85 | 1.03 | **0.83** | 2.92 | 3.64 | 4.31 | **3.62** | 2.84 | 3.68 | 4.09 | **3.54** | 2.85 | 3.81 | 4.07 | **3.58** | 2.69 | 3.59 | 3.89 | **3.39** |
| **N2** | 0.65 | 0.97 | 1.18 | **0.93** | 0.61 | 0.86 | 1.02 | **0.83** | 2.95 | 4.00 | 4.51 | **3.82** | 2.85 | 3.85 | 4.49 | **3.73** | 2.92 | 3.95 | 4.17 | **3.68** | 2.84 | 3.76 | 4.09 | **3.56** |
| **N3** | 0.65 | 0.97 | 1.18 | **0.93** | 0.61 | 0.85 | 1.02 | **0.83** | 2.96 | 3.99 | 4.49 | **3.81** | 3.11 | 3.88 | 4.54 | **3.84** | 2.93 | 3.87 | 4.08 | **3.63** | 2.80 | 3.71 | 4.09 | **3.53** |
| **N4** | 0.65 | 0.97 | 1.18 | **0.93** | 0.61 | 0.85 | 1.02 | **0.83** | 2.95 | 3.98 | 4.47 | **3.80** | 2.90 | 3.88 | 4.54 | **3.77** | 2.93 | 3.86 | 4.05 | **3.61** | 2.80 | 3.70 | 4.01 | **3.50** |
| **Mean** | **0.65** | **0.97** | **1.19** | **0.93** | **0.61** | **0.85** | **1.02** | **0.83** | **2.95** | **3.90** | **4.44** | **3.76** | **2.93** | **3.82** | **4.42** | **3.72** | **2.91** | **3.87** | **4.10** | **3.62** | **2.78** | **3.69** | **4.02** | **3.50** |

| | 30 DAS | | | | 60 DAS | | | | 90 DAS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | 0.002 | 0.008 | 0.0003 | 0.0012 | 0.024 | 0.094 | 0.003 | 0.012 | 0.049 | 0.192 | 0.030 | 0.1177 |
| **Plant Density (P)** | 0.003 | 0.008 | 0.0016 | 0.0063 | 0.025 | 0.068 | 0.007 | 0.028 | 0.049 | 0.136 | 0.033 | 0.1274 |
| **Nitrogen levels (N)** | 0.003 | 0.009 | 0.0018 | 0.0050 | 0.028 | 0.079 | 0.008 | 0.023 | 0.057 | 0.157 | 0.038 | 0.1039 |
| **I X P** | 0.005 | 0.013 | 0.0027 | 0.0075 | 0.043 | 0.118 | 0.012 | 0.034 | 0.085 | 0.236 | 0.056 | 0.1561 |
| **I X N** | 0.005 | 0.015 | 0.0031 | 0.0086 | 0.049 | 0.136 | 0.014 | 0.040 | 0.099 | 0.273 | 0.065 | 0.1802 |
| **P X N** | 0.005 | 0.015 | 0.0031 | 0.0086 | 0.049 | 0.136 | 0.014 | 0.040 | 0.099 | 0.273 | 0.065 | 0.1802 |
| **I X P X N** | 0.009 | 0.026 | 0.0054 | 0.0150 | 0.085 | 0.236 | 0.025 | 0.069 | 0.171 | 0.473 | 0.113 | 0.3118 |

DAS: Days after sowing

**Appendix 13. Leaf area index of maize at 120 DAS and physiological maturity as influenced by irrigation scheduling, plant density and nitrogen levels**

| Growth stages | 120 DAS | | | | | | | | Physiological maturity | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1998-1999 | | | | 1999-2000 | | | | 1998-1999 | | | | 1999-2000 | | | |
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 1.78 | 2.29 | 2.64 | **2.24** | 1.64 | 2.06 | 2.42 | **2.04** | 1.23 | 1.60 | 1.80 | **1.54** | 1.25 | 1.56 | 1.80 | **1.54** |
| $I_1N_2$ | 1.79 | 2.34 | 2.72 | **2.28** | 1.64 | 2.15 | 2.58 | **2.12** | 1.56 | 1.63 | 1.88 | **1.69** | 1.25 | 1.64 | 1.95 | **1.61** |
| $I_1N_3$ | 1.78 | 2.30 | 2.55 | **2.21** | 1.66 | 1.94 | 2.22 | **1.94** | 1.23 | 1.59 | 1.81 | **1.54** | 1.25 | 1.63 | 1.83 | **1.57** |
| $I_1N_4$ | 1.78 | 2.28 | 2.51 | **2.19** | 1.65 | 1.93 | 2.16 | **1.91** | 1.14 | 1.58 | 1.79 | **1.50** | 1.24 | 1.61 | 1.79 | **1.55** |
| **Mean** | **1.78** | **2.30** | **2.61** | **2.23** | **1.65** | **2.02** | **2.35** | **2.00** | **1.29** | **1.60** | **1.82** | **1.57** | **1.25** | **1.61** | **1.84** | **1.57** |
| $I_2N_1$ | 1.87 | 2.52 | 2.96 | **2.45** | 1.76 | 2.36 | 2.82 | **2.31** | 1.31 | 1.71 | 2.08 | **1.70** | 1.35 | 1.77 | 2.13 | **1.75** |
| $I_2N_2$ | 1.93 | 2.86 | 3.17 | **2.65** | 1.83 | 2.51 | 3.08 | **2.47** | 1.34 | 1.85 | 2.22 | **1.80** | 1.36 | 1.90 | 2.33 | **1.86** |
| $I_2N_3$ | 1.94 | 2.71 | 3.21 | **2.62** | 1.83 | 2.55 | 3.13 | **2.50** | 1.35 | 1.93 | 2.30 | **1.86** | 1.37 | 1.92 | 2.39 | **1.89** |
| $I_2N_4$ | 1.94 | 2.73 | 3.22 | **2.63** | 1.84 | 2.56 | 3.14 | **2.51** | 1.36 | 1.94 | 2.30 | **1.87** | 1.37 | 1.93 | 2.39 | **1.90** |
| **Mean** | **1.92** | **2.71** | **3.14** | **2.59** | **1.82** | **2.50** | **3.04** | **2.45** | **1.34** | **1.86** | **2.23** | **1.81** | **1.36** | **1.88** | **2.31** | **1.85** |
| $I_3N_1$ | 1.86 | 2.56 | 3.10 | **2.51** | 1.79 | 2.44 | 2.94 | **2.39** | 1.31 | 1.73 | 2.15 | **1.73** | 1.34 | 1.82 | 2.20 | **1.79** |
| $I_3N_2$ | 1.93 | 2.77 | 3.37 | **2.69** | 1.85 | 2.61 | 3.23 | **2.56** | 1.37 | 1.93 | 2.34 | **1.88** | 1.38 | 1.96 | 2.43 | **1.92** |
| $I_3N_3$ | 1.94 | 2.81 | 3.42 | **2.72** | 1.86 | 2.65 | 3.30 | **2.60** | 1.38 | 2.16 | 2.42 | **1.99** | 1.38 | 2.01 | 2.50 | **1.96** |
| $I_3N_4$ | 1.94 | 2.82 | 3.44 | **2.73** | 1.86 | 2.66 | 3.31 | **2.61** | 1.38 | 2.18 | 2.42 | **1.99** | 1.39 | 2.02 | 2.51 | **1.97** |
| **Mean** | **1.92** | **2.74** | **3.33** | **2.66** | **1.84** | **2.59** | **3.20** | **2.54** | **1.36** | **2.00** | **2.33** | **1.90** | **1.37** | **1.95** | **2.41** | **1.91** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 1.84 | 2.46 | 2.90 | **2.40** | 1.73 | 2.29 | 2.73 | **2.25** | 1.28 | 1.68 | 2.01 | **1.66** | 1.31 | 1.72 | 2.04 | 1.69 |
| **N2** | 1.88 | 2.66 | 3.09 | **2.54** | 1.77 | 2.42 | 2.96 | **2.39** | 1.42 | 1.80 | 2.15 | **1.79** | 1.33 | 1.83 | 2.24 | 1.80 |
| **N3** | 1.89 | 2.61 | 3.06 | **2.52** | 1.78 | 2.38 | 2.88 | **2.35** | 1.32 | 1.89 | 2.18 | **1.80** | 1.33 | 1.85 | 2.24 | 1.81 |
| **N4** | 1.89 | 2.61 | 3.06 | **2.52** | 1.78 | 2.38 | 2.87 | **2.35** | 1.29 | 1.90 | 2.17 | **1.79** | 1.33 | 1.85 | 2.23 | 1.81 |
| **Mean** | **1.87** | **2.58** | **3.03** | **2.49** | **1.77** | **2.37** | **2.86** | **2.33** | **1.33** | **1.82** | **2.13** | **1.76** | **1.33** | **1.81** | **2.19** | **1.78** |
| | **120 DAS** | | | | | | | | **Physiological maturity** | | | | | | | |
| **Comparing Means of** | **SEm ±** | | **CD ( 0.05)** | | **SEm ±** | | **CD ( 0.05)** | | **SEm ±** | | **CD ( 0.05)** | | **SEm ±** | | **CD ( 0.05)** | |
| **Irrigation (I)** | 0.028 | | 0.011 | | 0.002 | | 0.009 | | 0.018 | | 0.070 | | 0.003 | | 0.011 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Plant Density (P)** | 0.003 | 0.008 | 0.003 | 0.011 | 0.023 | 0.064 | 0.003 | 0.011 |
| **Nitrogen levels (N)** | 0.003 | 0.010 | 0.003 | 0.009 | 0.027 | 0.074 | 0.003 | 0.009 |
| **I X P** | 0.005 | 0.014 | 0.005 | 0.014 | 0.040 | 0.110 | 0.005 | 0.014 |
| **I X N** | 0.006 | 0.017 | 0.006 | 0.016 | 0.046 | 0.128 | 0.006 | 0.016 |
| **P X N** | 0.006 | 0.017 | 0.006 | 0.016 | 0.046 | 0.128 | 0.006 | 0.016 |
| **I X P X N** | 0.010 | 0.029 | 0.010 | 0.028 | 0.080 | 0.221 | 0.010 | 0.027 |

DAS: Days after sowing

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density : $P_1$ = 55555 Plants $ha^{-1}$; $P_2$ = 83333 Plants $ha^{-1}$; $P_3$ = 111111 Plants $ha^{-1}$.

Nitrogen levels (N) : $N_1$ = 75 Kg $ha^{-1}$; $N_2$ = 150 Kg $ha^{-1}$; $N_3$ = 225 Kg $ha^{-1}$; $N_4$ = 300 Kg $ha^{-1}$.

**Appendix 14 Leaf dry matter (g plant[1]) of maize at 30, 60 and 90 DAS as influenced by irrigation scheduling, plant density and nitrogen levels**

| Growth stages | 30 DAS | | | | | | | | 60 DAS | | | | | | | | 90 DAS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1998-1999 | | | | 1999-2000 | | | | 1998-1999 | | | | 1999-2000 | | | | 1998-1999 | | | | 1999-2000 | | | |
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 6.70 | 6.66 | 5.93 | **6.43** | 6.26 | 5.65 | 5.07 | **5.66** | 42.32 | 35.38 | 29.49 | **35.73** | 40.19 | 32.55 | 27.70 | **33.48** | 37.50 | 30.77 | 25.30 | **31.19** | 38.72 | 30.86 | 26.01 | **31.86** |
| $I_1N_2$ | 6.70 | 6.64 | 5.93 | **6.42** | 6.25 | 5.64 | 5.03 | **5.64** | 42.44 | 35.70 | 29.78 | **35.98** | 40.38 | 33.69 | 29.38 | **34.49** | 37.18 | 31.16 | 25.89 | **31.41** | 38.33 | 32.04 | 27.99 | **32.79** |
| $I_1N_3$ | 6.70 | 6.64 | 5.93 | **6.42** | 6.25 | 5.63 | 5.03 | **5.64** | 42.03 | 34.74 | 28.56 | **35.11** | 40.15 | 33.28 | 29.12 | **34.18** | 36.92 | 30.11 | 24.63 | **30.55** | 38.04 | 31.54 | 27.70 | **32.43** |
| $I_1N_4$ | 6.70 | 6.64 | 5.93 | **6.42** | 6.25 | 5.63 | 5.03 | **5.03** | 41.85 | 34.41 | 28.19 | **34.82** | 40.07 | 32.98 | 28.68 | **33.91** | 36.60 | 29.82 | 24.40 | **30.27** | 37.94 | 31.25 | 27.32 | **32.17** |
| **Mean** | **6.70** | **6.64** | **5.93** | **6.42** | **6.25** | **5.64** | **5.04** | **5.49** | **42.16** | **35.06** | **29.01** | **35.41** | **40.20** | **33.12** | **28.72** | **34.01** | **37.05** | **30.46** | **25.06** | **30.86** | **38.26** | **31.42** | **27.25** | **32.31** |
| $I_2N_1$ | 6.70 | 6.70 | 5.99 | **6.46** | 6.26 | 5.69 | 5.07 | **5.67** | 43.11 | 37.79 | 32.26 | **37.72** | 42.57 | 36.55 | 32.78 | **37.30** | 39.25 | 33.92 | 28.85 | **34.01** | 42.17 | 35.81 | 31.10 | **36.36** |
| $I_2N_2$ | 6.70 | 6.67 | 5.99 | **6.45** | 6.25 | 5.68 | 5.05 | **5.66** | 45.39 | 40.71 | 34.52 | **40.21** | 45.20 | 39.10 | 35.48 | **39.93** | 41.25 | 36.54 | 31.43 | **36.41** | 44.22 | 38.89 | 34.65 | **39.25** |
| $I_2N_3$ | 6.70 | 6.67 | 5.99 | **6.45** | 6.26 | 5.68 | 5.05 | **5.66** | 45.27 | 43.43 | 36.56 | **41.75** | 45.05 | 42.33 | 37.52 | **41.64** | 41.11 | 39.29 | 33.58 | **37.99** | 44.25 | 42.86 | 37.77 | **41.63** |
| $I_2N_4$ | 6.70 | 6.67 | 5.99 | **6.45** | 6.26 | 5.68 | 5.05 | **5.66** | 45.36 | 43.47 | 36.63 | **41.82** | 45.13 | 42.36 | 37.61 | **41.70** | 41.40 | 39.60 | 50.08 | **43.69** | 44.26 | 42.88 | 38.31 | **41.81** |
| **Mean** | **6.70** | **6.70** | **5.99** | **6.46** | **6.26** | **5.68** | **5.06** | **5.67** | **45.39** | **45.39** | **45.39** | **45.39** | **45.39** | **45.39** | **45.39** | **45.39** | **45.39** | **45.39** | **45.39** | **45.39** | **45.39** | **45.39** | **45.39** | **45.39** |
| $I_3N_1$ | 6.70 | 6.67 | 5.99 | **6.45** | 6.26 | 5.69 | 5.07 | **5.68** | 43.14 | 39.21 | 33.85 | **38.73** | 42.45 | 37.54 | 33.96 | **37.98** | 38.99 | 35.02 | 29.77 | **34.59** | 42.48 | 36.34 | 32.80 | **37.21** |
| $I_3N_2$ | 6.70 | 6.67 | 5.99 | **6.45** | 6.26 | 5.68 | 5.05 | **5.66** | 45.69 | 42.70 | 37.91 | **42.10** | 45.33 | 41.13 | 37.42 | **41.29** | 41.34 | 39.19 | 33.13 | **37.89** | 44.04 | 40.73 | 36.95 | **40.57** |
| $I_3N_3$ | 6.70 | 6.67 | 5.99 | **6.45** | 6.26 | 5.68 | 5.05 | **5.66** | 46.30 | 47.48 | 40.01 | **44.60** | 47.45 | 43.39 | 39.62 | **43.49** | 41.62 | 41.62 | 35.27 | **39.50** | 44.20 | 42.66 | 39.29 | **42.05** |
| $I_3N_4$ | 6.70 | 6.67 | 5.99 | **6.45** | 6.26 | 5.68 | 5.05 | **5.66** | 46.36 | 47.59 | 40.13 | **44.69** | 47.51 | 43.53 | 39.79 | **43.61** | 41.64 | 41.94 | 35.53 | **39.70** | 44.25 | 42.83 | 39.34 | **42.14** |
| **Mean** | **6.70** | **6.67** | **5.99** | **6.45** | **6.26** | **5.68** | **5.06** | **5.67** | **45.37** | **44.25** | **37.98** | **42.53** | **45.69** | **41.40** | **37.70** | **41.59** | **40.90** | **39.44** | **33.43** | **37.92** | **43.74** | **40.64** | **37.10** | **40.49** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 6.70 | 6.68 | 5.97 | **6.45** | 6.26 | 5.68 | 5.07 | **5.67** | 42.85 | 37.46 | 31.87 | **37.39** | 41.74 | 35.54 | 31.48 | **36.25** | 38.58 | 33.24 | 27.97 | **33.26** | 41.12 | 34.34 | 29.97 | **35.14** |
| **N2** | 6.70 | 6.66 | 5.97 | **6.44** | 6.25 | 5.66 | 5.05 | **5.65** | 44.51 | 39.70 | 34.07 | **39.43** | 43.64 | 37.97 | 34.10 | **38.57** | 39.92 | 35.63 | 30.15 | **35.24** | 42.20 | 37.22 | 33.20 | **37.54** |
| **N3** | 6.70 | 6.66 | 5.97 | **6.44** | 6.25 | 5.66 | 5.05 | **5.65** | 44.54 | 41.88 | 35.05 | **40.49** | 44.22 | 39.67 | 35.42 | **39.77** | 39.88 | 37.01 | 31.16 | **36.02** | 42.16 | 39.02 | 34.92 | **38.70** |
| **N4** | 6.70 | 6.66 | 5.97 | **6.44** | 6. | 5. | 5. | **5.6** | 44. | 41. | 34. | **40.** | 44. | 39. | 35. | **39.** | 39. | 37. | 36. | **37.** | 42. | 38. | 34. | **38.** |

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 25 | 66 | 05 | **5** | 52 | 83 | 99 | **45** | 24 | 62 | 36 | **74** | 88 | 12 | 67 | **89** | 15 | 98 | 99 | **71** |
| **Mean** | **6.70** | **6.67** | **5.97** | **6.44** | **6.26** | **5.67** | **5.05** | **5.66** | **44.11** | **40.22** | **33.99** | **39.44** | **43.46** | **38.20** | **34.09** | **38.58** | **39.57** | **35.75** | **31.49** | **35.60** | **41.91** | **37.39** | **33.27** | **37.52** |

| | **30 DAS** | | | | **60 DAS** | | | | **90 DAS** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | 0.004 | 0.015 | 0.009 | 0.035 | 0.034 | 0.132 | 0.028 | 0.109 | 0.039 | 0.151 | 0.039 | 0.153 |
| **Plant Density (P)** | 0.006 | 0.018 | 0.005 | 0.018 | 0.019 | 0.052 | 0.009 | 0.036 | 0.024 | 0.068 | 0.014 | 0.053 |
| **Nitrogen levels (N)** | 0.007 | 0.020 | 0.005 | 0.014 | 0.022 | 0.060 | 0.016 | 0.044 | 0.028 | 0.078 | 0.016 | 0.044 |
| **I X P** | 0.011 | 0.030 | 0.008 | 0.022 | 0.032 | 0.089 | 0.016 | 0.044 | 0.042 | 0.117 | 0.024 | 0.065 |
| **I X N** | 0.013 | 0.035 | 0.009 | 0.025 | 0.037 | 0.103 | 0.018 | 0.051 | 0.049 | 0.135 | 0.027 | 0.075 |
| **P X N** | 0.013 | 0.035 | 0.009 | 0.025 | 0.037 | 0.103 | 0.018 | 0.051 | 0.049 | 0.135 | 0.027 | 0.075 |
| **I X P X N** | 0.022 | 0.061 | 0.016 | 0.043 | 0.064 | 0.179 | 0.032 | 0.088 | 0.085 | 0.235 | 0.047 | 0.131 |

DAS: Days after sowing

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$.

Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$; $N_2$ = 150 Kg ha$^{-1}$;

$N_3$ = 225 Kg ha$^{-1}$; $N_4$ = 300 Kg ha$^{-1}$.

**Appendix 15. Leaf dry matter (g plant$^{1}$) of maize at 120 DAS and at physiological maturity as influenced by irrigation scheduling, plant density and nitrogen levels**

| Growth stages | 120 DAS | | | | | | | | Physiological maturity | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1998-1999 | | | | 1999-2000 | | | | 1998-1999 | | | | 1999-2000 | | | |
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 36.42 | 29.86 | 24.54 | 30.27 | 37.57 | 29.95 | 25.23 | 30.92 | 36.20 | 29.68 | 24.40 | 30.10 | 37.37 | 29.80 | 25.11 | 30.76 |
| $I_1N_2$ | 36.08 | 30.23 | 25.13 | 30.48 | 37.17 | 32.08 | 27.17 | 32.14 | 35.87 | 30.05 | 25.15 | 30.36 | 36.97 | 31.93 | 27.03 | 31.98 |
| $I_1N_3$ | 35.73 | 29.22 | 23.98 | 29.64 | 36.88 | 30.60 | 26.87 | 31.45 | 35.53 | 29.04 | 23.84 | 29.47 | 36.71 | 30.45 | 26.73 | 31.30 |
| $I_1N_4$ | 35.52 | 28.95 | 23.68 | 29.38 | 36.77 | 30.32 | 26.50 | 31.20 | 35.31 | 28.77 | 23.55 | 29.21 | 36.71 | 30.16 | 26.37 | 31.08 |
| Mean | 35.94 | 29.57 | 24.33 | 29.95 | 37.10 | 30.74 | 26.44 | 31.43 | 35.73 | 29.39 | 24.24 | 29.78 | 36.94 | 30.59 | 26.31 | 31.28 |
| $I_2N_1$ | 38.09 | 32.93 | 28.00 | 33.01 | 40.93 | 34.75 | 30.17 | 35.28 | 37.86 | 32.73 | 27.84 | 32.81 | 40.72 | 33.60 | 30.03 | 34.78 |
| $I_2N_2$ | 42.31 | 36.05 | 31.34 | 36.56 | 43.64 | 37.81 | 34.41 | 38.62 | 40.10 | 35.24 | 30.26 | 35.20 | 43.25 | 36.95 | 33.35 | 37.85 |
| $I_2N_3$ | 43.08 | 39.29 | 34.78 | 39.05 | 43.93 | 41.97 | 37.71 | 41.20 | 40.10 | 37.36 | 32.31 | 36.59 | 43.27 | 39.00 | 35.52 | 39.26 |
| $I_2N_4$ | 43.23 | 39.44 | 35.05 | 39.24 | 43.93 | 42.11 | 37.98 | 41.34 | 40.10 | 37.35 | 32.30 | 36.58 | 43.31 | 39.08 | 36.13 | 39.51 |
| Mean | 41.68 | 36.93 | 32.29 | 36.97 | 43.11 | 39.16 | 35.07 | 39.11 | 39.54 | 35.67 | 30.68 | 35.29 | 42.64 | 37.16 | 33.76 | 37.85 |
| $I_3N_1$ | 38.00 | 33.99 | 29.66 | 33.88 | 41.24 | 36.25 | 31.83 | 36.44 | 37.77 | 33.78 | 29.66 | 33.74 | 40.04 | 35.06 | 31.67 | 35.59 |
| $I_3N_2$ | 41.25 | 39.28 | 34.09 | 38.21 | 43.63 | 39.43 | 35.81 | 39.62 | 40.11 | 37.68 | 32.92 | 36.90 | 42.36 | 38.34 | 34.69 | 38.46 |
| $I_3N_3$ | 41.65 | 42.92 | 37.30 | 40.62 | 43.93 | 42.77 | 38.49 | 41.73 | 40.12 | 40.21 | 35.12 | 38.48 | 42.92 | 41.62 | 37.92 | 40.82 |
| $I_3N_4$ | 41.74 | 43.02 | 37.31 | 40.69 | 44.21 | 42.92 | 38.57 | 41.90 | 40.15 | 40.22 | 35.12 | 38.50 | 43.22 | 41.64 | 37.95 | 40.94 |
| Mean | 40.66 | 39.80 | 34.59 | 38.35 | 43.25 | 40.34 | 36.18 | 39.92 | 39.54 | 37.97 | 33.21 | 36.90 | 42.13 | 39.17 | 35.56 | 38.95 |
| P X N Interaction | P1 | P2 | P3 | Mean | P1 | P2 | P3 | Mean | P1 | P2 | P3 | Mean | P1 | P2 | P3 | Mean |
| N1 | 37.50 | 32.26 | 27.40 | 32.39 | 39.91 | 33.65 | 29.08 | 34.21 | 37.28 | 32.07 | 27.30 | 32.21 | 39.37 | 32.82 | 28.94 | 33.71 |
| N2 | 39.88 | 35.19 | 30.18 | 35.08 | 41.48 | 36.44 | 32.46 | 36.79 | 38.69 | 34.32 | 29.44 | 34.15 | 40.86 | 35.74 | 31.69 | 36.10 |
| N3 | 40.15 | 37.14 | 32.02 | 36.44 | 41.58 | 38.45 | 34.36 | 38.13 | 38.58 | 35.54 | 30.42 | 34.85 | 40.97 | 37.02 | 33.39 | 37.13 |
| N4 | 40.16 | 37.13 | 32.01 | 36.44 | 41.64 | 38.45 | 34.35 | 38.15 | 38.52 | 35.44 | 30.32 | 34.76 | 41.08 | 36.96 | 33.49 | 37.18 |
| Mean | 39.42 | 35.43 | 30.40 | 35.09 | 41.15 | 36.75 | 32.56 | 36.82 | 38.27 | 34.34 | 29.37 | 33.99 | 40.57 | 35.64 | 31.88 | 36.03 |

| | 120 DAS | | | | Physiological maturity | | | |
|---|---|---|---|---|---|---|---|---|
| Comparing Means of | SEm ± | CD ( 0.05) | SEm ± | CD ( 0.05) | SEm ± | CD ( 0.05) | SEm ± | CD ( 0.05) |
| Irrigation (I) | 0.042 | 0.165 | 0.042 | 0.166 | 0.033 | 0.013 | 0.037 | 0.145 |
| Plant Density (P) | 0.014 | 0.038 | 0.011 | 0.031 | 0.011 | 0.031 | 0.011 | 0.032 |
| Nitrogen levels (N) | 0.016 | 0.044 | 0.013 | 0.036 | 0.013 | 0.036 | 0.013 | 0.035 |
| I X P | 0.024 | 0.065 | 0.019 | 0.054 | 0.019 | 0.054 | 0.019 | 0.053 |
| I X N | 0.027 | 0.076 | 0.022 | 0.062 | 0.022 | 0.062 | 0.022 | 0.061 |
| P X N | 0.027 | 0.076 | 0.022 | 0.062 | 0.022 | 0.062 | 0.022 | 0.061 |
| I X P X N | 0.047 | 0.131 | 0.039 | 0.108 | 0.039 | 0.110 | 0.038 | 0.108 |

DAS: Days after sowing

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$.

Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$; $N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$; $N_4$ = 300 Kg ha$^{-1}$.

Appendix 16. Stem dry matter (g plant[1]) of maize at 30, 60 and 90 DAS as influenced by irrigation scheduling, plant density and nitrogen levels

| Growth stages | 30 DAS | | | | | | | | 60 DAS | | | | | | | | 90 DAS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1998-1999 | | | | 1999-2000 | | | | 1998-1999 | | | | 1999-2000 | | | | 1998-1999 | | | | 1999-2000 | | | |
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 0.22 | 0.22 | 0.22 | **0.22** | 0.21 | 0.21 | 0.21 | **0.21** | 31.60 | 26.14 | 21.66 | **26.47** | 28.38 | 22.71 | 19.07 | **23.39** | 53.80 | 44.90 | 37.68 | **45.46** | 51.04 | 41.37 | 34.12 | **42.18** |
| $I_1N_2$ | 0.22 | 0.22 | 0.22 | **0.22** | 0.21 | 0.21 | 0.21 | **0.21** | 32.66 | 28.14 | 23.32 | **28.04** | 29.43 | 24.40 | 20.86 | **24.89** | 53.94 | 48.16 | 41.32 | **47.81** | 50.92 | 43.49 | 38.05 | **44.15** |
| $I_1N_3$ | 0.22 | 0.22 | 0.22 | **0.22** | 0.21 | 0.21 | 0.21 | **0.21** | 32.72 | 27.61 | 22.55 | **27.63** | 29.30 | 24.33 | 21.11 | **24.91** | 53.17 | 46.32 | 38.90 | **46.13** | 49.34 | 42.26 | 37.33 | **42.98** |
| $I_1N_4$ | 0.22 | 0.22 | 0.22 | **0.22** | 0.21 | 0.21 | 0.21 | **0.21** | 32.37 | 27.48 | 22.37 | **27.41** | 29.16 | 24.04 | 20.82 | **24.67** | 52.88 | 45.77 | 38.62 | **45.76** | 49.12 | 41.85 | 36.85 | **42.60** |
| **Mean** | **0.22** | **0.22** | **0.22** | **0.22** | **0.21** | **0.21** | **0.21** | **0.21** | **32.34** | **27.34** | **22.48** | **27.39** | **29.07** | **23.87** | **20.46** | **24.47** | **53.45** | **46.29** | **39.13** | **46.29** | **50.11** | **42.24** | **36.59** | **42.98** |
| $I_2N_1$ | 0.22 | 0.22 | 0.22 | **0.22** | 0.21 | 0.21 | 0.21 | **0.21** | 31.13 | 28.00 | 23.93 | **27.69** | 30.11 | 26.10 | 22.21 | **26.14** | 54.47 | 46.81 | 40.39 | **47.23** | 53.43 | 45.77 | 38.29 | **45.83** |
| $I_2N_2$ | 0.22 | 0.22 | 0.22 | **0.22** | 0.21 | 0.21 | 0.21 | **0.21** | 33.62 | 31.57 | 27.00 | **30.73** | 32.12 | 29.06 | 24.60 | **28.60** | 58.52 | 55.43 | 49.26 | **54.40** | 57.63 | 53.98 | 46.25 | **52.62** |
| $I_2N_3$ | 0.22 | 0.22 | 0.22 | **0.22** | 0.21 | 0.21 | 0.21 | **0.21** | 33.91 | 34.51 | 29.25 | **32.56** | 32.46 | 30.62 | 26.62 | **29.90** | 58.67 | 58.64 | 52.26 | **56.52** | 57.62 | 57.04 | 49.12 | **54.59** |
| $I_2N_4$ | 0.22 | 0.22 | 0.22 | **0.22** | 0.21 | 0.21 | 0.21 | **0.21** | 34.04 | 34.55 | 29.20 | **32.60** | 32.55 | 30.73 | 26.67 | **29.98** | 58.95 | 58.95 | 52.70 | **56.87** | 57.62 | 47.27 | 48.50 | **51.13** |
| **Mean** | **0.22** | **0.22** | **0.22** | **0.22** | **0.21** | **0.21** | **0.21** | **0.21** | **33.17** | **32.16** | **27.34** | **30.89** | **31.81** | **29.13** | **25.03** | **28.65** | **57.65** | **54.96** | **48.65** | **53.75** | **56.58** | **51.02** | **45.54** | **51.04** |
| $I_3N_1$ | 0.22 | 0.22 | 0.22 | **0.22** | 0.21 | 0.21 | 0.21 | **0.21** | 30.92 | 27.42 | 23.47 | **27.27** | 29.87 | 25.69 | 21.75 | **25.77** | 53.98 | 45.76 | 39.00 | **46.25** | 52.79 | 44.70 | 37.11 | **44.87** |
| $I_3N_2$ | 0.22 | 0.22 | 0.22 | **0.22** | 0.21 | 0.21 | 0.21 | **0.21** | 33.96 | 32.04 | 27.60 | **31.20** | 32.29 | 29.05 | 25.25 | **28.86** | 58.52 | 55.61 | 49.22 | **54.45** | 57.71 | 54.20 | 45.82 | **52.58** |
| $I_3N_3$ | 0.22 | 0.22 | 0.22 | **0.22** | 0.21 | 0.21 | 0.21 | **0.21** | 34.07 | 34.47 | 29.74 | **32.76** | 32.51 | 31.14 | 27.27 | **30.31** | 59.14 | 58.75 | 52.56 | **56.82** | 57.81 | 57.55 | 48.32 | **54.56** |
| $I_3N_4$ | 0.22 | 0.22 | 0.22 | **0.22** | 0.21 | 0.21 | 0.21 | **0.21** | 34.24 | 34.59 | 29.84 | **32.89** | 32.63 | 31.24 | 27.53 | **30.47** | 59.25 | 59.03 | 52.65 | **56.98** | 57.82 | 57.62 | 48.40 | **54.61** |
| **Mean** | **0.22** | **0.22** | **0.22** | **0.22** | **0.21** | **0.21** | **0.21** | **0.21** | **33.30** | **32.13** | **27.66** | **31.03** | **31.83** | **29.28** | **25.45** | **28.85** | **57.73** | **54.79** | **48.36** | **53.62** | **56.53** | **53.52** | **44.91** | **51.65** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 0.22 | 0.22 | 0.22 | **0.22** | 0.21 | 0.21 | 0.21 | **0.21** | 31.22 | 27.19 | 23.02 | **27.14** | 29.46 | 24.84 | 21.01 | **25.10** | 54.09 | 45.83 | 39.02 | **46.31** | 52.42 | 43.95 | 36.51 | **44.29** |
| **N2** | 0.22 | 0.22 | 0.22 | **0.22** | 0.21 | 0.21 | 0.21 | **0.21** | 33.41 | 30.58 | 25.97 | **29.99** | 31.28 | 27.51 | 23.57 | **27.45** | 56.99 | 53.07 | 46.60 | **52.22** | 55.42 | 50.56 | 43.37 | **49.78** |
| **N3** | 0.22 | 0.22 | 0.22 | **0.22** | 0.21 | 0.21 | 0.21 | **0.21** | 33.57 | 32.20 | 27.18 | **30.98** | 31.42 | 28.70 | 25.00 | **28.37** | 56.99 | 54.57 | 47.90 | **53.16** | 54.92 | 52.28 | 44.92 | **50.71** |
| **N4** | 0.22 | 0.22 | 0.22 | **0.22** | 0.21 | 0.21 | 0.21 | **0.21** | 33.55 | 32.21 | 27.14 | **30.96** | 31.45 | 28.67 | 25.01 | **28.37** | 57.03 | 54.58 | 47.99 | **53.20** | 54.85 | 48.92 | 44.58 | **49.45** |
| **Mean** | **0.22** | **0.22** | **0.22** | **0.22** | **0.21** | **0.21** | **0.21** | **0.21** | **32.94** | **30.54** | **25.83** | **29.77** | **30.90** | **27.43** | **23.65** | **27.32** | **56.28** | **52.01** | **45.38** | **51.22** | **54.40** | **48.93** | **42.35** | **48.56** |

| | 30 DAS | | | | 60 DAS | | | | 90 DAS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | NS | NS | NS | NS | 0.022 | 0.086 | 0.014 | 0.055 | 0.038 | 0.148 | 0.522 | 2.050 |
| **Plant Density (P)** | NS | NS | NS | NS | 0.022 | 0.062 | 0.021 | 0.058 | 0.019 | 0.053 | 0.489 | 1.916 |
| **Nitrogen levels (N)** | NS | NS | NS | NS | 0.015 | 0.041 | 0.014 | 0.039 | 0.022 | 0.061 | 0.564 | 1.564 |
| **I X P** | NS | NS | NS | NS | 0.022 | 0.062 | 0.021 | 0.058 | 0.033 | 0.091 | 0.847 | 2.347 |
| **I X N** | NS | NS | NS | NS | 0.258 | 0.715 | 0.243 | 0.670 | 0.038 | 0.105 | 0.978 | 2.710 |
| **P X N** | NS | NS | NS | NS | 0.258 | 0.715 | 0.243 | 0.670 | 0.038 | 0.105 | 0.978 | 2.710 |
| **I X P X N** | NS | NS | NS | NS | 0.045 | 0.124 | 0.042 | 0.116 | 0.066 | 0.183 | 1.693 | 4.693 |

DAS: Days after sowing

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants $ha^{-1}$; $P_2$ = 83333 Plants $ha^{-1}$; $P_3$ = 111111 Plants $ha^{-1}$.

Nitrogen levels (N) : $N_1$ = 75 Kg $ha^{-1}$; $N_2$ = 150 Kg $ha^{-1}$; $N_3$ = 225 Kg $ha^{-1}$; $N_4$ = 300 Kg $ha^{-1}$.

Appendix 17. Stem dry matter (g plant$^{1}$) of maize at 120 DAS and physiological maturity as influenced by irrigation scheduling, plant density and nitrogen levels

| Growth stages | 120 DAS | | | | | | | | Physiological maturity | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1998-1999 | | | | 1999-2000 | | | | 1998-1999 | | | | 1999-2000 | | | |
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 53.81 | 44.90 | 37.71 | **45.47** | 50.01 | 41.37 | 34.12 | **41.83** | 51.93 | 44.62 | 37.68 | **44.74** | 48.86 | 41.77 | 34.12 | **41.58** |
| $I_1N_2$ | 53.94 | 48.16 | 41.36 | **47.82** | 50.38 | 43.59 | 38.25 | **44.07** | 53.94 | 48.16 | 41.32 | **47.81** | 50.35 | 43.49 | 38.05 | **43.96** |
| $I_1N_3$ | 53.16 | 46.32 | 39.19 | **46.23** | 50.32 | 42.26 | 37.33 | **43.30** | 52.53 | 45.98 | 38.61 | **45.71** | 49.93 | 42.02 | 36.94 | **42.96** |
| $I_1N_4$ | 52.88 | 46.00 | 38.62 | **45.83** | 49.87 | 41.85 | 36.93 | **42.88** | 52.23 | 45.70 | 38.38 | **45.44** | 49.77 | 41.67 | 36.59 | **5.03** |
| **Mean** | **53.45** | **46.35** | **39.22** | **46.34** | **50.15** | **42.27** | **36.66** | **43.02** | **52.66** | **46.12** | **39.00** | **45.92** | **49.73** | **42.24** | **36.42** | **33.39** |
| $I_2N_1$ | 54.14 | 46.81 | 40.40 | **47.12** | 48.41 | 45.76 | 38.29 | **44.15** | 48.76 | 46.08 | 40.40 | **45.08** | 43.36 | 45.70 | 38.29 | **42.45** |
| $I_2N_2$ | 58.52 | 56.41 | 49.55 | **54.83** | 57.62 | 53.98 | 46.96 | **52.85** | 58.43 | 55.43 | 49.38 | **54.41** | 57.55 | 53.00 | 46.87 | **52.47** |
| $I_2N_3$ | 58.79 | 60.63 | 54.23 | **57.88** | 58.90 | 59.29 | 52.02 | **56.74** | 58.62 | 59.91 | 53.32 | **57.29** | 57.57 | 59.09 | 51.43 | **56.03** |
| $I_2N_4$ | 59.05 | 60.92 | 54.53 | **58.17** | 58.95 | 59.49 | 52.07 | **56.84** | 58.73 | 59.91 | 54.13 | **57.59** | 57.42 | 59.15 | 50.87 | **55.81** |
| **Mean** | **57.62** | **56.19** | **49.68** | **54.50** | **55.97** | **54.63** | **47.33** | **52.64** | **56.14** | **55.33** | **49.31** | **53.59** | **53.98** | **54.24** | **46.86** | **51.69** |
| $I_3N_1$ | 53.18 | 45.76 | 39.30 | **46.08** | 47.13 | 44.72 | 37.11 | **42.99** | 47.53 | 45.10 | 39.00 | **43.88** | 42.00 | 44.71 | 37.11 | **41.27** |
| $I_3N_2$ | 58.52 | 56.59 | 49.55 | **54.89** | 57.71 | 54.27 | 46.98 | **52.99** | 57.18 | 56.19 | 49.43 | **54.27** | 57.37 | 54.20 | 46.82 | **52.80** |
| $I_3N_3$ | 59.12 | 60.33 | 55.51 | **58.32** | 58.95 | 60.29 | 52.05 | **57.09** | 58.86 | 59.71 | 54.92 | **57.83** | 57.68 | 59.29 | 51.95 | **56.31** |
| $I_3N_4$ | 59.14 | 60.53 | 55.60 | **58.43** | 58.98 | 60.32 | 52.12 | **57.14** | 58.87 | 59.86 | 54.92 | **57.88** | 57.71 | 59.44 | 52.07 | **56.40** |
| **Mean** | **57.49** | **55.80** | **49.99** | **54.43** | **55.69** | **54.90** | **47.06** | **52.55** | **55.61** | **55.22** | **49.57** | **53.46** | **53.69** | **54.41** | **46.99** | **51.70** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 53.71 | 45.83 | 39.14 | **46.22** | 48.52 | 43.95 | 36.50 | **42.99** | 49.41 | 45.27 | 39.03 | **44.57** | 44.74 | 44.06 | 36.50 | **41.77** |
| **N2** | 57.00 | 53.72 | 46.82 | **52.51** | 55.24 | 50.61 | 44.06 | **49.97** | 56.52 | 53.26 | 46.71 | **52.16** | 55.09 | 50.23 | 43.91 | **49.75** |
| **N3** | 57.03 | 55.76 | 49.64 | **54.14** | 56.06 | 53.95 | 47.13 | **52.38** | 56.67 | 55.20 | 48.95 | **53.61** | 55.06 | 53.47 | 46.77 | **51.77** |
| **N4** | 57.02 | 55.81 | 49.59 | **54.14** | 55.93 | 53.89 | 47.04 | **52.29** | 56.61 | 55.16 | 49.14 | **53.64** | 54.97 | 53.42 | 46.51 | **51.63** |
| **Mean** | **56.19** | **52.78** | **46.30** | **51.75** | **53.94** | **50.60** | **43.68** | **49.41** | **54.80** | **52.22** | **45.96** | **50.99** | **52.46** | **50.30** | **43.42** | **48.73** |

| | **120 DAS** | | | | **Physiological maturity** | | | |
|---|---|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | 0.041 | 0.159 | 0.060 | 0.236 | 0.041 | 0.160 | 0.439 | 1.723 |
| **Plant Density (P)** | 0.016 | 0.045 | 0.020 | 0.055 | 0.017 | 0.047 | 0.475 | 1.862 |
| **Nitrogen levels (N)** | 0.019 | 0.052 | 0.023 | 0.064 | 0.020 | 0.055 | 0.549 | 1.521 |
| **I X P** | 0.028 | 0.078 | 0.035 | 0.096 | 0.030 | 0.082 | 0.823 | 2.281 |
| **I X N** | 0.032 | 0.090 | 0.040 | 0.111 | 0.034 | 0.095 | 0.950 | 2.634 |
| **P X N** | 0.032 | 0.090 | 0.040 | 0.111 | 0.034 | 0.095 | 0.950 | 2.634 |
| **I X P X N** | 0.056 | 0.155 | 0.069 | 0.192 | 0.059 | 0.165 | 1.646 | 4.562 |

DAS: Days after sowing

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$.

Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$; $N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$; $N_4$ = 300 Kg ha$^{-1.}$

**Appendix 18. Cob dry matter (g plant[1]) of maize at 90,120 DAS and at physiological maturity as influenced by irrigation scheduling, plant density and nitrogen levels**

| Growth stages | 90 DAS | | | | | | | | 120 DAS | | | | | | | | Physiological maturity | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1998-1999 | | | | 1999-2000 | | | | 1998-1999 | | | | 1999-2000 | | | | 1998-1999 | | | | 1999-2000 | | | |
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 60.78 | 48.61 | 39.70 | **49.70** | 67.36 | 49.60 | 37.59 | **51.51** | 144.41 | 101.61 | 77.71 | **107.91** | 150.94 | 103.09 | 76.73 | **110.25** | 156.60 | 109.50 | 83.52 | **116.54** | 160.39 | 109.40 | 81.51 | **117.10** |
| $I_1N_2$ | 61.44 | 52.76 | 44.41 | **52.87** | 65.22 | 52.66 | 43.08 | **53.65** | 145.31 | 113.22 | 93.27 | **117.27** | 148.21 | 111.72 | 92.58 | **117.50** | 159.01 | 124.81 | 100.52 | **128.12** | 159.32 | 119.08 | 98.53 | **125.64** |
| $I_1N_3$ | 60.44 | 50.25 | 40.25 | **50.31** | 62.97 | 48.04 | 39.24 | **50.08** | 140.23 | 104.09 | 82.25 | **108.86** | 140.96 | 100.16 | 80.89 | **107.33** | 151.61 | 111.06 | 98.35 | **120.34** | 152.14 | 106.33 | 97.80 | **118.76** |
| $I_1N_4$ | 60.25 | 49.64 | 39.71 | **49.87** | 62.63 | 47.49 | 38.40 | **49.51** | 139.94 | 103.13 | 81.22 | **108.10** | 139.25 | 99.62 | 79.27 | **106.05** | 151.27 | 110.77 | 87.14 | **116.39** | 150.87 | 105.41 | 87.07 | **114.45** |
| **Mean** | **60.73** | **50.32** | **41.02** | **50.69** | **64.55** | **49.45** | **39.58** | **51.19** | **142.47** | **105.51** | **83.61** | **110.53** | **144.84** | **103.65** | **82.37** | **110.28** | **154.62** | **114.04** | **92.38** | **120.35** | **155.68** | **110.06** | **91.23** | **118.99** |
| $I_2N_1$ | 60.76 | 47.59 | 39.39 | **49.24** | 68.94 | 50.87 | 38.48 | **52.76** | 147.15 | 100.27 | 75.44 | **107.62** | 158.90 | 103.19 | 75.01 | **112.36** | 164.61 | 110.90 | 82.76 | **119.42** | 174.92 | 112.05 | 81.18 | **122.72** |
| $I_2N_2$ | 64.70 | 57.31 | 46.80 | **56.27** | 73.48 | 61.32 | 47.36 | **60.72** | 155.47 | 123.99 | 99.26 | **126.24** | 176.23 | 129.31 | 101.92 | **135.82** | 176.80 | 137.85 | 109.64 | **141.43** | 185.05 | 142.32 | 112.03 | **146.47** |
| $I_2N_3$ | 64.85 | 62.09 | 49.80 | **58.92** | 73.70 | 63.59 | 50.20 | **62.50** | 156.47 | 132.18 | 104.52 | **131.06** | 177.14 | 137.82 | 110.63 | **141.86** | 176.93 | 144.45 | 116.31 | **145.89** | 186.04 | 147.45 | 118.21 | **150.57** |
| $I_2N_4$ | 64.95 | 62.39 | 50.08 | **59.14** | 73.78 | 63.62 | 50.29 | **62.57** | 156.84 | 133.13 | 108.56 | **132.84** | 177.15 | 138.35 | 110.28 | **141.93** | 176.90 | 144.72 | 137.29 | **152.97** | 186.73 | 147.54 | 119.42 | **151.23** |
| **Mean** | **63.81** | **57.35** | **46.52** | **55.89** | **72.48** | **59.85** | **46.59** | **59.64** | **153.98** | **122.39** | **96.94** | **124.44** | **172.36** | **127.17** | **99.46** | **132.99** | **173.81** | **134.48** | **111.50** | **139.93** | **183.19** | **137.34** | **107.71** | **142.75** |
| $I_3N_1$ | 60.01 | 46.14 | 37.95 | **48.03** | 68.25 | 49.62 | 37.20 | **51.69** | 146.43 | 97.95 | 72.56 | **105.64** | 158.85 | 100.05 | 72.29 | **110.40** | 163.81 | 108.31 | 79.85 | **117.32** | 173.65 | 108.58 | 77.98 | **120.07** |
| $I_3N_2$ | 64.43 | 55.21 | 46.45 | **55.36** | 63.30 | 61.47 | 47.45 | **57.41** | 155.51 | 124.01 | 98.96 | **126.16** | 176.51 | 130.63 | 101.53 | **136.22** | 176.82 | 138.48 | 109.44 | **141.58** | 185.41 | 142.32 | 111.61 | **146.45** |
| $I_3N_3$ | 64.88 | 62.07 | 49.90 | **58.95** | 73.77 | 64.30 | 50.86 | **62.97** | 156.94 | 134.17 | 107.66 | **132.92** | 177.49 | 138.31 | 109.69 | **141.83** | 176.82 | 145.20 | 116.54 | **146.19** | 186.18 | 147.85 | 117.60 | **150.54** |
| $I_3N_4$ | 65.53 | 62.39 | 59.12 | **62.35** | 74.29 | 64.42 | 51.70 | **63.47** | 157.48 | 137.07 | 108.51 | **134.35** | 177.85 | 138.69 | 110.05 | **142.20** | 176.83 | 146.19 | 116.84 | **146.62** | 186.73 | 148.73 | 118.79 | **151.42** |
| **Mean** | **63.71** | **56.45** | **48.36** | **56.17** | **69.90** | **59.95** | **46.80** | **58.89** | **154.09** | **123.30** | **96.92** | **124.77** | **172.68** | **126.92** | **98.39** | **132.66** | **173.57** | **134.55** | **105.67** | **137.93** | **182.99** | **136.87** | **106.50** | **142.12** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| **N1** | 60.51 | 47.45 | 39.01 | **48.99** | 68.18 | 50.03 | 37.76 | **51.99** | 146.00 | 99.94 | 75.23 | **107.06** | 156.23 | 102.11 | 74.68 | **111.01** | 161.67 | 109.57 | 82.04 | **117.76** | 169.65 | 110.01 | 80.22 | **119.96** |
| **N2** | 63.52 | 55.09 | 45.89 | **54.83** | 67.33 | 58.48 | 45.96 | **57.26** | 152.10 | 120.41 | 97.16 | **123.22** | 166.98 | 123.89 | 98.67 | **129.85** | 170.88 | 133.71 | 106.53 | **137.04** | 176.60 | 134.57 | 107.39 | **139.52** |
| **N3** | 63.39 | 58.14 | 46.65 | **56.06** | 70.15 | 58.64 | 46.77 | **58.52** | 151.21 | 123.48 | 98.15 | **124.28** | 165.20 | 125.43 | 100.40 | **130.34** | 168.45 | 133.57 | 110.40 | **137.47** | 174.79 | 133.88 | 111.20 | **139.96** |
| **N4** | 63.57 | 58.14 | 49.64 | **57.12** | 70.23 | 58.51 | 46.80 | **58.52** | 151.42 | 124.44 | 99.43 | **125.10** | 164.75 | 125.55 | 99.87 | **130.06** | 168.33 | 133.89 | 113.76 | **138.66** | 174.78 | 133.89 | 108.43 | **139.03** |
| **Mean** | **62.75** | **54.70** | **45.30** | **54.25** | **68.97** | **56.42** | **44.32** | **56.57** | **150.18** | **117.07** | **92.49** | **119.91** | **163.29** | **119.25** | **93.40** | **125.31** | **167.33** | **127.69** | **103.18** | **132.73** | **173.95** | **128.09** | **101.81** | **134.62** |

| | 90 DAS | | | | 120 DAS | | | | Physiological maturity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | 0.098 | 0.386 | 0.571 | 2.243 | 0.125 | 0.491 | 0.114 | 0.448 | 1.009 | 3.961 | 1.270 | 4.985 |
| **Plant Density (P)** | 0.097 | 0.271 | 0.482 | 1.889 | 0.185 | 0.512 | 0.089 | 0.350 | 0.956 | 2.650 | 0.871 | 2.414 |
| **Nitrogen levels (N)** | 0.113 | 0.313 | 0.556 | 1.542 | 0.213 | 0.591 | 0.155 | 0.429 | 1.104 | 3.060 | 1.006 | 2.788 |
| **I X P** | 0.163 | 0.453 | 0.835 | 2.313 | 0.185 | 0.512 | 0.089 | 0.350 | 1.656 | 4.590 | 1.509 | 4.188 |
| **I X N** | 0.196 | 0.542 | 0.964 | 2.671 | 0.369 | 1.024 | 0.179 | 0.495 | 1.912 | 5.301 | 1.742 | 4.828 |
| **P X N** | 0.196 | 0.542 | 0.964 | 2.671 | 0.369 | 1.024 | 0.179 | 0.495 | 1.912 | 5.301 | 1.742 | 4.828 |
| **I X P X N** | 0.339 | 0.939 | 0.669 | 1.855 | 0.694 | 1.923 | 0.309 | 0.858 | 3.312 | 9.180 | 3.018 | 8.365 |

DAS: Days after sowing  Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants $ha^{-1}$; $P_2$ = 83333 Plants $ha^{-1}$; $P_3$ = 111111 Plants $ha^{-1}$.  Nitrogen levels (N) : $N_1$ = 75 Kg $ha^{-1}$; $N_2$ = 150 Kg $ha^{-1}$; $N_3$ = 225 Kg $ha^{-1}$; $N_4$ = 300 Kg $ha^{-1}$.

## Appendix 19. Total dry matter (g plant$^{-1}$) of maize at 30, 60 and 90 DAS as influenced by irrigation scheduling, plant density and nitrogen levels

| Growth stages | 30 DAS | | | | | | | | 60 DAS | | | | | | | | 90 DAS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1998-1999 | | | | 1999-2000 | | | | 1998-1999 | | | | 1999-2000 | | | | 1998-1999 | | | | 1999-2000 | | | |
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 6.92 | 6.88 | 6.15 | **6.65** | 6.47 | 5.86 | 5.28 | **5.87** | 73.92 | 61.52 | 51.15 | **62.20** | 68.57 | 55.26 | 46.77 | **56.87** | 152.08 | 124.28 | 102.68 | **126.35** | 157.12 | 121.83 | 97.72 | **125.56** |
| $I_1N_2$ | 6.92 | 6.86 | 6.15 | **6.64** | 6.46 | 5.85 | 5.24 | **5.85** | 75.10 | 63.84 | 53.10 | **64.01** | 69.81 | 58.09 | 50.24 | **59.38** | 152.56 | 132.08 | 111.62 | **132.09** | 154.47 | 128.19 | 109.12 | **130.59** |
| $I_1N_3$ | 6.92 | 6.86 | 6.15 | **6.64** | 6.46 | 5.84 | 5.24 | **5.85** | 74.75 | 62.35 | 51.11 | **62.74** | 69.45 | 57.61 | 50.23 | **59.10** | 150.53 | 126.68 | 103.78 | **127.00** | 150.35 | 121.84 | 104.27 | **125.49** |
| $I_1N_4$ | 6.92 | 6.86 | 6.15 | **6.64** | 6.46 | 5.84 | 5.24 | **5.85** | 74.22 | 61.89 | 50.56 | **62.22** | 69.23 | 57.02 | 49.50 | **58.58** | 149.73 | 125.23 | 102.73 | **125.90** | 149.69 | 120.59 | 102.57 | **124.28** |
| **Mean** | **6.92** | **6.87** | **6.15** | **6.65** | **6.46** | **5.85** | **5.25** | **5.85** | **74.50** | **62.40** | **51.48** | **62.79** | **69.27** | **57.00** | **49.19** | **58.48** | **151.23** | **127.07** | **105.20** | **127.83** | **152.91** | **123.11** | **103.42** | **126.48** |
| $I_2N_1$ | 6.92 | 6.92 | 6.21 | **6.68** | 6.47 | 5.90 | 5.28 | **5.88** | 74.24 | 65.79 | 56.19 | **65.41** | 72.68 | 62.65 | 54.99 | **63.44** | 154.48 | 128.32 | 108.63 | **130.48** | 164.54 | 132.45 | 107.87 | **134.95** |
| $I_2N_2$ | 6.92 | 6.89 | 6.21 | **6.67** | 6.46 | 5.89 | 5.26 | **5.87** | 79.01 | 72.28 | 61.52 | **70.94** | 77.32 | 68.16 | 60.08 | **68.52** | 164.47 | 149.28 | 127.49 | **147.08** | 175.33 | 154.19 | 128.26 | **152.59** |
| $I_2N_3$ | 6.92 | 6.89 | 6.21 | **6.67** | 6.47 | 5.89 | 5.26 | **5.87** | 79.18 | 77.94 | 65.81 | **74.31** | 77.51 | 72.95 | 64.14 | **71.53** | 164.63 | 160.02 | 135.64 | **153.43** | 175.57 | 163.49 | 137.09 | **158.72** |
| $I_2N_4$ | 6.92 | 6.89 | 6.21 | **6.67** | 6.47 | 5.89 | 5.26 | **5.87** | 79.40 | 78.02 | 65.83 | **74.42** | 77.68 | 73.09 | 64.28 | **71.68** | 165.30 | 160.94 | 152.86 | **159.70** | 175.66 | 153.77 | 137.10 | **155.51** |
| **Mean** | **6.92** | **6.90** | **6.21** | **6.68** | **6.47** | **5.89** | **5.27** | **5.88** | **77.96** | **73.51** | **62.34** | **71.27** | **76.30** | **69.21** | **60.87** | **68.79** | **162.22** | **149.64** | **131.16** | **147.67** | **172.78** | **150.98** | **127.58** | **150.44** |
| $I_3N_1$ | 6.92 | 6.89 | 6.21 | **6.67** | 6.47 | 5.90 | 5.28 | **5.88** | 74.06 | 66.63 | 57.32 | **66.00** | 72.32 | 63.23 | 55.71 | **63.75** | 152.98 | 126.92 | 106.72 | **128.87** | 163.52 | 130.66 | 107.11 | **133.76** |
| $I_3N_2$ | 6.92 | 6.89 | 6.21 | **6.67** | 6.47 | 5.89 | 5.26 | **5.87** | 79.65 | 74.74 | 65.51 | **73.30** | 77.62 | 70.18 | 62.67 | **70.16** | 164.29 | 150.01 | 128.80 | **147.70** | 165.05 | 156.40 | 130.22 | **150.56** |
| $I_3N_3$ | 6.92 | 6.89 | 6.21 | **6.67** | 6.47 | 5.89 | 5.26 | **5.87** | 80.37 | 81.95 | 69.75 | **77.36** | 79.96 | 74.53 | 66.89 | **73.79** | 165.64 | 162.44 | 137.73 | **155.27** | 175.78 | 164.51 | 138.47 | **159.59** |
| $I_3N_4$ | 6.92 | 6.89 | 6.21 | **6.67** | 6.47 | 5.89 | 5.26 | **5.87** | 80.60 | 82.18 | 69.97 | **77.58** | 80.14 | 74.77 | 67.32 | **74.08** | 166.42 | 163.36 | 147.30 | **159.03** | 176.36 | 164.87 | 139.44 | **160.22** |
| **Mean** | **6.92** | **6.89** | **6.21** | **6.67** | **6.47** | **5.89** | **5.27** | **5.88** | **78.67** | **76.38** | **65.64** | **73.56** | **77.51** | **70.68** | **63.15** | **70.45** | **162.33** | **150.68** | **130.14** | **147.72** | **170.18** | **154.11** | **128.81** | **151.03** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| N1 | 6.92 | 6.90 | 6.19 | **6.67** | 6.47 | 5.89 | 5.28 | **5.88** | 74.07 | 64.65 | 54.89 | **64.54** | 71.19 | 60.38 | 52.49 | **61.35** | 153.18 | 126.51 | 106.01 | **128.57** | 161.73 | 128.31 | 104.23 | **131.42** |
| N2 | 6.92 | 6.88 | 6.19 | **6.66** | 6.46 | 5.88 | 5.25 | **5.86** | 77.92 | 70.29 | 60.04 | **69.42** | 74.92 | 65.48 | 57.66 | **66.02** | 160.44 | 143.79 | 122.64 | **142.29** | 164.95 | 146.26 | 122.53 | **144.58** |
| N3 | 6.92 | 6.88 | 6.19 | **6.66** | 6.47 | 5.87 | 5.25 | **5.86** | 78.10 | 74.08 | 62.22 | **71.47** | 75.64 | 68.36 | 60.42 | **68.14** | 160.27 | 149.71 | 125.72 | **145.23** | 167.23 | 149.95 | 126.61 | **147.93** |
| N4 | 6.92 | 6.88 | 6.19 | **6.66** | 6.47 | 5.87 | 5.25 | **5.86** | 78.07 | 74.03 | 62.12 | **71.41** | 75.68 | 68.29 | 60.37 | **68.11** | 160.48 | 149.84 | 134.30 | **148.21** | 167.24 | 146.41 | 126.37 | **146.67** |
| **Mean** | **6.92** | **6.88** | **6.19** | **6.66** | **6.47** | **5.88** | **5.26** | **5.87** | **77.04** | **70.76** | **59.82** | **69.21** | **74.36** | **65.63** | **57.74** | **65.91** | **158.59** | **142.46** | **122.17** | **141.07** | **165.29** | **142.73** | **119.94** | **142.65** |

| | 30 DAS | | | | 60 DAS | | | | 90 DAS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Comparing Means of** | SEm ± | CD ( 0.05) | SEm ± | CD ( 0.05) | SEm ± | CD ( 0.05) | SEm ± | CD ( 0.05) | SEm ± | CD ( 0.05) | SEm ± | CD ( 0.05) |
| **Irrigation (I)** | 0.104 | 0.409 | 0.006 | 0.216 | 0.046 | 0.180 | 0.042 | 0.166 | 0.105 | 0.410 | 0.130 | 0.512 |
| **Plant Density (P)** | 0.097 | 0.268 | 0.004 | 0.137 | 0.023 | 0.064 | 0.015 | 0.103 | 0.052 | 0.144 | 0.057 | 0.225 |
| **Nitrogen levels (N)** | 0.117 | 0.324 | 0.004 | 0.111 | 0.027 | 0.074 | 0.018 | 0.084 | 0.060 | 0.166 | 0.066 | 0.184 |
| **I X P** | 0.168 | 0.464 | 0.006 | 0.166 | 0.040 | 0.110 | 0.026 | 0.049 | 0.090 | 0.249 | 0.099 | 0.275 |
| **I X N** | 0.193 | 0.536 | 0.007 | 0.194 | 0.046 | 0.127 | 0.030 | 0.084 | 0.104 | 0.287 | 0.115 | 0.318 |
| **P X N** | 0.193 | 0.536 | 0.007 | 0.194 | 0.046 | 0.127 | 0.030 | 0.084 | 0.104 | 0.287 | 0.115 | 0.318 |
| **I X P X N** | 0.335 | 0.929 | 0.012 | 0.333 | 0.079 | 0.220 | 0.052 | 0.145 | 0.180 | 0.498 | 0.199 | 0.550 |

DAS: Days after sowing

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants ha$^{-1}$; $P_2$ = 83333 Plants ha$^{-1}$; $P_3$ = 111111 Plants ha$^{-1}$.

Nitrogen levels (N) : $N_1$ = 75 Kg ha$^{-1}$; $N_2$ = 150 Kg ha$^{-1}$; $N_3$ = 225 Kg ha$^{-1}$; $N_4$ = 300 Kg ha$^{-1}$.

**Appendix 20.Total dry matter (g plant[1]) of maize at 120 DAS and at physiological maturity as influenced by irrigation scheduling, plant density and nitrogen levels**

| Growth stages | 120 DAS | | | | | | | | Physiological maturity | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1998-1999 | | | | 1999-2000 | | | | 1998-1999 | | | | 1999-2000 | | | |
| Treatments | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean | $P_1$ | $P_2$ | $P_3$ | Mean |
| $I_1N_1$ | 234.64 | 176.37 | 139.96 | **183.66** | 238.52 | 174.41 | 136.08 | **183.00** | 244.73 | 183.80 | 145.60 | **191.38** | 246.62 | 180.97 | 140.74 | **189.44** |
| $I_1N_2$ | 235.33 | 191.61 | 159.76 | **195.57** | 235.76 | 187.39 | 158.00 | **193.72** | 248.82 | 203.02 | 166.99 | **206.28** | 246.64 | 194.50 | 163.61 | **201.58** |
| $I_1N_3$ | 229.12 | 179.63 | 145.42 | **184.72** | 228.16 | 173.02 | 145.09 | **182.09** | 239.67 | 186.08 | 160.80 | **195.52** | 238.78 | 178.80 | 161.47 | **193.02** |
| $I_1N_4$ | 228.34 | 178.08 | 143.52 | **183.31** | 225.89 | 171.79 | 142.70 | **180.13** | 238.81 | 185.24 | 149.07 | **191.04** | 237.35 | 177.24 | 150.03 | **188.21** |
| Mean | **231.86** | **181.42** | **147.17** | **186.82** | **232.08** | **176.65** | **145.47** | **184.73** | **243.01** | **189.54** | **155.62** | **196.05** | **242.35** | **182.88** | **153.96** | **193.06** |
| $I_2N_1$ | 239.38 | 180.01 | 143.84 | **187.74** | 248.24 | 183.70 | 143.47 | **191.80** | 251.23 | 189.71 | 151.00 | **197.31** | 259.00 | 191.35 | 149.50 | **199.95** |
| $I_2N_2$ | 256.30 | 216.45 | 180.15 | **217.63** | 277.49 | 221.10 | 183.29 | **227.29** | 275.33 | 228.52 | 189.28 | **231.04** | 285.85 | 232.27 | 192.25 | **236.79** |
| $I_2N_3$ | 258.34 | 232.10 | 193.53 | **227.99** | 279.97 | 239.08 | 200.36 | **239.80** | 275.65 | 241.72 | 201.94 | **239.77** | 286.88 | 245.54 | 205.16 | **245.86** |
| $I_2N_4$ | 259.12 | 233.49 | 198.14 | **230.25** | 280.03 | 239.95 | 200.33 | **240.10** | 275.73 | 241.98 | 223.72 | **247.14** | 287.46 | 245.77 | 206.42 | **246.55** |
| Mean | **253.29** | **215.51** | **178.92** | **215.90** | **271.43** | **220.96** | **181.86** | **224.75** | **269.49** | **225.48** | **191.49** | **228.82** | **279.80** | **228.73** | **188.33** | **232.29** |
| $I_3N_1$ | 237.61 | 177.70 | 141.52 | **185.61** | 247.22 | 181.02 | 141.23 | **189.82** | 249.11 | 187.19 | 148.51 | **194.94** | 255.69 | 188.35 | 146.76 | **196.93** |
| $I_3N_2$ | 255.28 | 219.88 | 182.60 | **219.25** | 277.85 | 224.33 | 184.32 | **228.83** | 274.11 | 232.35 | 191.79 | **232.75** | 285.14 | 234.86 | 193.12 | **237.71** |
| $I_3N_3$ | 257.71 | 237.42 | 200.47 | **231.87** | 280.37 | 241.37 | 200.23 | **240.66** | 275.80 | 245.12 | 206.58 | **242.50** | 286.78 | 248.76 | 207.47 | **247.67** |
| $I_3N_4$ | 258.36 | 240.62 | 201.42 | **233.47** | 281.04 | 241.93 | 200.74 | **241.24** | 275.85 | 246.27 | 206.88 | **243.00** | 287.66 | 249.81 | 208.81 | **248.76** |
| Mean | **252.24** | **218.91** | **181.50** | **217.55** | **271.62** | **222.16** | **181.63** | **225.14** | **268.72** | **227.73** | **188.44** | **228.30** | **278.82** | **230.45** | **189.04** | **232.77** |
| **P X N Interaction** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** | **P1** | **P2** | **P3** | **Mean** |
| N1 | 237.21 | 178.03 | 141.77 | **185.67** | 244.66 | 179.71 | 140.26 | **188.21** | 248.36 | 186.90 | 148.37 | **194.54** | 253.77 | 186.89 | 145.67 | **195.44** |
| N2 | 248.97 | 209.31 | 174.17 | **210.82** | 263.70 | 210.94 | 175.20 | **216.61** | 266.09 | 221.30 | 182.69 | **223.36** | 272.54 | 220.54 | 182.99 | **225.36** |
| N3 | 248.39 | 216.38 | 179.81 | **214.86** | 262.83 | 217.82 | 181.89 | **220.85** | 263.71 | 224.31 | 189.77 | **225.93** | 270.81 | 224.37 | 191.37 | **228.85** |
| N4 | 248.61 | 217.40 | 181.03 | **215.68** | 262.32 | 217.89 | 181.26 | **220.49** | 263.46 | 224.50 | 193.22 | **227.06** | 270.82 | 224.27 | 188.42 | **227.84** |
| Mean | **245.79** | **205.28** | **169.19** | **206.76** | **258.38** | **206.59** | **169.65** | **211.54** | **260.40** | **214.25** | **178.51** | **217.72** | **266.99** | **214.02** | **177.11** | **219.37** |

| | 120 DAS | | | | Physiological maturity | | | |
|---|---|---|---|---|---|---|---|---|
| **Comparing Means of** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** | **SEm ±** | **CD ( 0.05)** |
| **Irrigation (I)** | 0.156 | 0.611 | 0.204 | 0.801 | 0.169 | 0.662 | 0.209 | 0.820 |
| **Plant Density (P)** | 0.096 | 0.265 | 0.108 | 0.300 | 0.109 | 0.302 | 0.111 | 0.436 |
| **Nitrogen levels (N)** | 0.110 | 0.306 | 0.125 | 0.346 | 0.126 | 0.349 | 0.128 | 0.356 |
| **I X P** | 0.166 | 0.459 | 0.187 | 0.519 | 0.189 | 0.524 | 0.193 | 0.534 |
| **I X N** | 0.191 | 0.530 | 0.216 | 0.599 | 0.218 | 0.605 | 0.222 | 0.616 |
| **P X N** | 0.191 | 0.530 | 0.216 | 0.599 | 0.218 | 0.605 | 0.222 | 0.616 |
| **I X P X N** | 0.331 | 0.918 | 0.374 | 1.038 | 0.380 | 1.048 | 0.385 | 1.067 |

DAS: Days after sowing

Irrigation Scheduling (I) : $I_1$ = 0.6 IW/CPE ratio; $I_2$ = 0.9 IW / CPE ratio; $I_3$ = 1.2 IW / CPE ratio.

Plant Density(P) : $P_1$ = 55555 Plants $ha^{-1}$; $P_2$ = 83333 Plants $ha^{-1}$; $P_3$ = 111111 Plants $ha^{-1}$.

Nitrogen levels (N) : $N_1$ = 75 Kg $ha^{-1}$; $N_2$ = 150 Kg $ha^{-1}$; $N_3$ = 225 Kg $ha^{-1}$; $N_4$ = 300 Kg $ha^{-1}$.

## Appendix 21. Economics of maize varieties as influenced by planting dates

| Treatments | Cost of production $ha^{-1}$ | | | Gross return @ Rs. $ha^{-1}$ | | | Net return @ Rs. $ha^{-1}$ | | | Benefit cost ratio | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-99 | 1999-2000 | Mean | 1998-99 | 1999-2000 | Mean | 1998-99 | 1999-2000 | Mean | 1998-99 | 1999-2000 | Mean |
| $D_1V_1$ | 13723 | 13994 | **13858** | 35582 | 37447 | **36515** | 21859 | 23454 | **22656** | 2.59 | 2.68 | **2.63** |
| $D_1V_2$ | 14082 | 14309 | **14196** | 40068 | 41393 | **40730** | 25985 | 27084 | **26535** | 2.85 | 2.89 | **2.87** |
| $D_1V_3$ | 14316 | 14548 | **14432** | 42874 | 44279 | **43577** | 28558 | 29732 | **29145** | 2.99 | 3.04 | **3.02** |
| $D_1V_4$ | 13641 | 13780 | **13710** | 34554 | 34769 | **34662** | 20913 | 20990 | **20951** | 2.53 | 2.52 | **2.53** |
| $D_1V_5$ | 12725 | 12792 | **12758** | 22261 | 21464 | **21862** | 9536 | 8671 | **9104** | 1.75 | 1.68 | **1.71** |
| **Mean** | **13697** | **13884** | **13791** | **35068** | **35871** | **35469** | **21370** | **21986** | **21678** | **2.54** | **2.56** | **2.55** |
| $D_2V_1$ | 13683 | 14025 | **13854** | 34905 | 37793 | **36349** | 21223 | 23767 | **22495** | 2.55 | 2.69 | **2.62** |
| $D_2V_2$ | 14079 | 14347 | **14213** | 39915 | 41799 | **40857** | 25836 | 27452 | **26644** | 2.84 | 2.91 | **2.87** |
| $D_2V_3$ | 14398 | 14704 | **14551** | 43811 | 46220 | **45015** | 29413 | 31516 | **30464** | 3.04 | 3.14 | **3.09** |
| $D_2V_4$ | 13597 | 13802 | **13699** | 33834 | 35003 | **34419** | 20238 | 21201 | **20719** | 2.49 | 2.54 | **2.51** |
| $D_2V_5$ | 12465 | 12718 | **12591** | 18782 | 20557 | **19670** | 6318 | 7839 | **7078** | 1.51 | 1.62 | **1.56** |
| **Mean** | **13644** | **13919** | **13782** | **34250** | **36274** | **35262** | **20605** | **22355** | **21480** | **2.48** | **2.58** | **2.53** |
| $D_3V_1$ | 13523 | 13959 | **13741** | 33034 | 36998 | **35016** | 19511 | 23039 | **21275** | 2.44 | 2.65 | **2.55** |
| $D_3V_2$ | 13758 | 14272 | **14015** | 35976 | 40911 | **38444** | 22218 | 26639 | **24428** | 2.61 | 2.87 | **2.74** |
| $D_3V_3$ | 14095 | 14576 | **14335** | 40170 | 44674 | **42422** | 26076 | 30098 | **28087** | 2.85 | 3.06 | **2.96** |
| $D_3V_4$ | 13394 | 13746 | **13570** | 31424 | 34335 | **32879** | 18030 | 20589 | **19309** | 2.35 | 2.50 | **2.42** |
| $D_3V_5$ | 12436 | 12680 | **12558** | 18432 | 20156 | **19294** | 5995 | 7476 | **6736** | 1.48 | 1.59 | **1.54** |
| **Mean** | **13441** | **13846** | **13644** | **31807** | **35415** | **33611** | **18366** | **21568** | **19967** | **2.35** | **2.53** | **2.44** |
| $D_4V_1$ | 13513 | 13989 | **13751** | 32875 | 37324 | **35099** | 19362 | 23335 | **21348** | 2.43 | 2.67 | **2.55** |
| $D_4V_2$ | 13854 | 14362 | **14108** | 37138 | 41959 | **39549** | 23284 | 27597 | **25441** | 2.68 | 2.92 | **2.80** |
| $D_4V_3$ | 14025 | 14587 | **14306** | 39160 | 44697 | **41928** | 25134 | 30110 | **27622** | 2.79 | 3.06 | **2.93** |
| $D_4V_4$ | 13393 | 13845 | **13619** | 31368 | 35517 | **33443** | 17975 | 21672 | **19824** | 2.34 | 2.57 | **2.46** |
| $D_4V_5$ | 12409 | 12597 | **12503** | 18225 | 18825 | **18525** | 5816 | 6228 | **6022** | 1.47 | 1.49 | **1.48** |
| **Mean** | **13439** | **13876** | **13657** | **31753** | **35664** | **33709** | **18314** | **21789** | **20051** | **2.34** | **2.54** | **2.44** |

Planting dates (D) : $D_1$ = Oct I fortnight ; $D_2$ = Oct II fortnight ; $D_3$ = Nov I fortnight ; $D_4$ = Nov II fortnight.

Varieties (V) : $V_1$ = Deccan 103 ; $V_2$ = DMH – 1 ; $V_3$ = DMH – 2 ; $V_4$ = Prabha (G-57) ; $V_5$ = Renuka (G-25).

## Appendix 22. Economics of maize as influenced by irrigation scheduling, plant density and nitrogen levels

| Treatments | Cost of production @ Rs. $ha^{-1}$ | | | Gross return @ Rs. $ha^{-1}$ | | | Net return @ Rs. $ha^{-1}$ | | | Benefit cost Ratio | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-99 | 1999-00 | Mean | 1998-99 | 1999-00 | Mean | 1998-99 | 1999-00 | Mean | 1998-99 | 1999-00 | Mean |
| I1P1N1 | 12545 | 12766 | **12655** | 32117 | 33985 | **33051** | 19572 | 21219 | **20396** | 2.56 | 2.66 | **2.61** |
| I1P1N2 | 13078 | 13331 | **13205** | 32877 | 34419 | **33648** | 19799 | 21088 | **20444** | 2.51 | 2.58 | **2.55** |
| I1P1N3 | 13526 | 13754 | **13640** | 31870 | 32419 | **32144** | 18344 | 18664 | **18504** | 2.36 | 2.36 | **2.36** |
| I1P1N4 | 14149 | 14444 | **14297** | 31859 | 32502 | **32181** | 17710 | 18058 | **17884** | 2.25 | 2.25 | **2.25** |
| **Mean** | **13324** | **13574** | **13449** | **32181** | **33331** | **32756** | **18856** | **19758** | **19307** | **2.42** | **2.46** | **2.44** |
| I1P2N1 | 13175 | 13401 | **13288** | 31365 | 33173 | **32269** | 18190 | 19772 | **18981** | 2.38 | 2.48 | **2.43** |
| I1P2N2 | 14007 | 14200 | **14104** | 35983 | 36649 | **36316** | 21976 | 22449 | **22212** | 2.57 | 2.58 | **2.57** |
| I1P2N3 | 14316 | 14502 | **14409** | 33156 | 33077 | **33116** | 18840 | 18575 | **18707** | 2.32 | 2.28 | **2.30** |
| I1P2N4 | 14909 | 15168 | **15038** | 32724 | 32843 | **32784** | 17815 | 17676 | **17745** | 2.19 | 2.17 | **2.18** |
| **Mean** | **14102** | **14318** | **14210** | **33307** | **33936** | **33621** | **19205** | **19618** | **19411** | **2.37** | **2.38** | **2.37** |
| I1P3N1 | 13560 | 13792 | **13676** | 30704 | 32502 | **31603** | 17144 | 18710 | **17927** | 2.26 | 2.36 | **2.31** |
| I1P3N2 | 14526 | 14730 | **14628** | 37084 | 37860 | **37472** | 22558 | 23130 | **22844** | 2.55 | 2.57 | **2.56** |
| I1P3N3 | 14814 | 15121 | **14968** | 33888 | 35395 | **34642** | 19074 | 20273 | **19674** | 2.29 | 2.34 | **2.31** |
| I1P3N4 | 15407 | 15759 | **15583** | 33444 | 34807 | **34126** | 18037 | 19048 | **18542** | 2.17 | 2.21 | **2.19** |
| **Mean** | **14577** | **14851** | **14714** | **33780** | **35141** | **34461** | **19204** | **20290** | **19747** | **2.32** | **2.37** | **2.34** |
| I2P1N1 | 13064 | 13372 | **13218** | 34867 | 37817 | **36342** | 21803 | 24445 | **23124** | 2.67 | 2.83 | **2.75** |
| I2P1N2 | 13762 | 14214 | **13988** | 37869 | 42017 | **39943** | 24107 | 27803 | **25955** | 2.75 | 2.96 | **2.85** |
| I2P1N3 | 14305 | 14820 | **14562** | 38099 | 42284 | **40191** | 23794 | 27464 | **25629** | 2.66 | 2.85 | **2.76** |
| I2P1N4 | 14928 | 15444 | **15186** | 38066 | 41579 | **39822** | 23138 | 26134 | **24636** | 2.55 | 2.69 | **2.62** |
| **Mean** | **14015** | **14463** | **14239** | **37225** | **40924** | **39075** | **23210** | **26462** | **24836** | **2.66** | **2.83** | **2.75** |
| I2P2N1 | 13585 | 13778 | **13682** | 32870 | 34439 | **33655** | 19285 | 20661 | **19973** | 2.42 | 2.50 | **2.46** |
| I2P2N2 | 14695 | 15118 | **14907** | 41315 | 44931 | **43123** | 26619 | 29813 | **28216** | 2.81 | 2.97 | **2.89** |
| I2P2N3 | 15440 | 15884 | **15662** | 44125 | 47303 | **45714** | 28686 | 31419 | **30053** | 2.86 | 2.98 | **2.92** |
| I2P2N4 | 16081 | 16583 | **16332** | 44347 | 47616 | **45981** | 28265 | 31033 | **29649** | 2.76 | 2.87 | **2.81** |
| **Mean** | **14950** | **15341** | **15145** | **40664** | **43572** | **42118** | **25714** | **28231** | **26973** | **2.71** | **2.83** | **2.77** |
| I2P3N1 | 13847 | 14047 | **13947** | 30786 | 32303 | **31544** | 16939 | 18257 | **17598** | 2.22 | 2.30 | **2.26** |
| I2P3N2 | 15265 | 15713 | **15489** | 43121 | 47018 | **45069** | 27856 | 31305 | **29581** | 2.82 | 2.99 | **2.91** |
| I2P3N3 | 16095 | 16582 | **16339** | 47023 | 49572 | **48297** | 30927 | 32990 | **31959** | 2.92 | 2.99 | **2.96** |
| I2P3N4 | 16732 | 17261 | **16996** | 47161 | 49425 | **48293** | 30429 | 32165 | **31297** | 2.82 | 2.86 | **2.84** |
| **Mean** | **15485** | **15901** | **15693** | **42022** | **44580** | **43301** | **26538** | **28679** | **27608** | **2.70** | **2.79** | **2.74** |
| I3P1N1 | 13363 | 13686 | **13524** | 34693 | 37953 | **36323** | 21330 | 24267 | **22798** | 2.60 | 2.77 | **2.68** |
| I3P1N2 | 14049 | 14420 | **14235** | 37704 | 40829 | **39267** | 23655 | 26409 | **25032** | 2.68 | 2.83 | **2.76** |
| I3P1N3 | 14587 | 15077 | **14832** | 37868 | 41789 | **39829** | 23281 | 26712 | **24997** | 2.60 | 2.77 | **2.68** |
| I3P1N4 | 15236 | 15786 | **15511** | 38186 | 42125 | **40156** | 22950 | 26339 | **24645** | 2.51 | 2.67 | **2.59** |
| **Mean** | **14309** | **14742** | **14525** | **37113** | **40674** | **38894** | **22804** | **25932** | **24368** | **2.60** | **2.76** | **2.68** |
| I3P2N1 | 13827 | 13975 | **13901** | 32124 | 33132 | **32628** | 18297 | 19157 | **18727** | 2.32 | 2.37 | **2.35** |
| I3P2N2 | 15005 | 15418 | **15211** | 41477 | 44979 | **43228** | 26472 | 29561 | **28016** | 2.76 | 2.92 | **2.84** |
| I3P2N3 | 15782 | 16210 | **15996** | 44687 | 47784 | **46235** | 28906 | 31573 | **30239** | 2.83 | 2.95 | **2.89** |
| I3P2N4 | 16422 | 16914 | **16668** | 44676 | 48058 | **46367** | 28254 | 31144 | **29699** | 2.72 | 2.84 | **2.78** |
| **Mean** | **15259** | **15629** | **15444** | **40741** | **43488** | **42115** | **25482** | **27859** | **26670** | **2.66** | **2.77** | **2.71** |
| I3P3N1 | 14059 | 14270 | **14165** | 29679 | 31344 | **30511** | 15620 | 17074 | **16347** | 2.11 | 2.20 | **2.15** |
| I3P3N2 | 15537 | 16036 | **15786** | 42852 | 47366 | **45109** | 27315 | 31330 | **29322** | 2.76 | 2.95 | **2.86** |
| I3P3N3 | 16364 | 16818 | **16591** | 46791 | 50063 | **48427** | 30427 | 33245 | **31836** | 2.86 | 2.98 | **2.92** |
| I3P3N4 | 17010 | 17504 | **17257** | 47045 | 50121 | **48583** | 30034 | 32617 | **31326** | 2.77 | 2.86 | **2.81** |
| **Mean** | **15743** | **16157** | **15950** | **41591** | **44723** | **43157** | **25849** | **28566** | **27208** | **2.62** | **2.75** | **2.69** |

Irrigation Scheduling (I) :-$I_1$ = 0.6 IW/CPE ratio, $I_2$ = 0.9 IW / CPE ratio, $I_3$ = 1.2 IW / CPE ratio,

Plant Population :- $P_1$ = 55555 Plants $ha^{-1}$, $P_2$ = 83333 Plants $ha^{-1}$, $P_3$ = 111111 Plants $ha^{-1}$,

Nitrogen levels (N) :- $N_1$ = 75 Kg $ha^{-1}$, $N_2$ = 150 Kg $ha^{-1}$, $N_3$ = 225 Kg $ha^{-1}$, $N_4$ = 300 Kg $ha^{-1}$

# STUDIES ON OPTIMIZATION OF AGROTECHNIQUES TO MAXIMISE PRODUCTIVITY OF WINTER MAIZE (*Zea Mays* L.) AND EVALUATION OF DSSAT v 3.5 CERES MAIZE MODEL

**NAGARAJU** **2006** **MAJOR ADVISOR : Dr. Y.B. PALLED**

## ABSTRACT

Two field experiments were conducted at Agricultural College farm Dharwad during *rabi* seasons of 1998-99 and 1999-2000 under irrigated condition. The results revealed that the single cross maize hybrid DMH-2 planted during II and / or I fortnight of October recorded significantly higher grain yield (8553 and 8255 kg $ha^{-1}$ respectively), net returns (Rs.30165 and 29145 $ha^{-1}$ respectively) and B: C ratio (3.09 and 3.02 respectively) over other treatment combinations.

Irrigation scheduling at 0.9 IW: CPE ratio coupled with plant density of 111111 plants $ha^{-1}$ and 150 per cent recommended nitrogen application (225 kg $ha^{-1}$ ) produced significantly higher grain yield (8894 kg $ha^{-1}$), net returns (Rs 31959 $ha^{-1}$) and B:C ratio (2.96) as compared to other treatment combinations.

The required genetic co-efficients for maize varieties were generated with the help of GENCALC programme. The simulation studies on growth and yield due to the effect of genotypes and planting dates, irrigation scheduling coupled with plant densities and nitrogen levels carried out by making use of minimum data sets such as weather, soil and experimental details. The CERES maize simulation results on growth and yield of maize viz., LAI, days to anthesis and maturity, grain, stover and biomass yield, harvest index, grain weight, grains $ear^{-1}$, grain number $m^{-2}$, water used and nitrogen uptake were very accurate and within the permissible tendency (less than 10 percent) towards over estimation and/ or under estimation except for leaf number $plant^{-1}$ where in CERES model over estimated to the extent of more than ten percent which emphasized the need for precise estimation of PHINT value. In addition, the simulated $NO_3$ nitrogen accumulation, $NO_3$ nitrogen leaching and drainage water helped in the interpretation of input use such as water and nitrogen. It is concluded that DSSAT v 3.5 maize model is very robust in predicting the growth and yield of maize as influenced by agro-techniques and could be used in wider perspective.