

**Effect of Plant Geometry and Fertility Levels on Productivity of
Various Elite Sorghum [*Sorghum bicolor* (L.) Moench] Genotypes**

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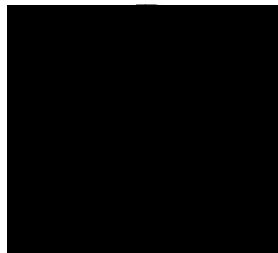
Thesis

Submitted to the

**Maharana Pratap University of Agriculture and Technology, Udaipur
*in partial fulfillment of the requirement for the degree of***

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(Agronomy)



By

HARISH KUMAR SUMERIYA

2006

**MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND
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CERTIFICATE-I

Dated : / /2006

This is to certify that **Mr. Harish Kumar Sumeriya** has successfully completed the Preliminary Examination held on 16/01/2006 as required under the regulation for the degree of **Doctor of Philosophy** in Agriculture.

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CERTIFICATE-II

Dated : / /2006

This is to certify that the thesis entitled “**Effect of plant geometry and fertility levels on productivity of various elite sorghum [*Sorghum bicolor* (L.) Moench] genotypes**” submitted for the degree of **Doctor of Philosophy in Agriculture** in the subject of **Agronomy**, embodies bonafide research work carried out by **Mr. Harish Kumar Sumeriya** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of this thesis was also approved by the advisory committee on 09/10/2006.

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Dated : 23 / 04 /2007

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Effect of Plant Geometry and Fertility Levels on Productivity of Various Elite Sorghum [*Sorghum bicolor* (L.) Moench] Genotypes

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ABSTRACT

A field experiment entitled “Effect of plant geometry and fertility levels on productivity of various elite sorghum [*Sorghum bicolor* (L.) Moench] genotypes” was conducted during two consecutive *kharif* seasons of 2003 and 2004 on clay loam soils at Instructional Farm, Rajasthan College of Agriculture, Udaipur. The objectives of experiments were to work out the most appropriate crop geometry and fertility level for higher productivity (grain as well as fodder) of sorghum. The soil of the experimental field was clay loam in texture with medium in available nitrogen (286.50 and 290.75 kg ha⁻¹) and phosphorus (19.50 and 19.95 kg ha⁻¹) and high in available potassium (389.00 and 392.00 kg ha⁻¹) and alkaline in reaction with pH 8.0 and 8.10, respectively during 2003 and 2004. The experiment consisted of 36 treatment combinations and replicated three times was set out in split plot design with three genotypes [CSV 15, SPV 1430 (Pratap Jowar 1430) and CSH 14] and three plant (crop) geometries (45 x 15, 45 x 10 and 30 x 10 cm as 1.50, 2.20 and 3.30 lac plants ha⁻¹) as main plots and four fertility levels i.e. 50, 75, 100 (80 kg N + 40 kg P₂O₅ ha⁻¹) and 125% RDF as sub plot treatments.

Amongst genotypes of sorghum, CSV 15 came out as most promising when judged in terms of plant height and dry matter accumulation per plant at various stages of crop growth and panicle length. The aforesaid variety also recorded significantly highest fodder and biological yield, nitrogen uptake by grain, phosphorus uptake by grain and total uptake by the crop compared to CSH 14 and SPV 1430.

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As regards to minimum days to flowering and maturity total weight and grain weight panicle⁻¹, grains per panicle, test weight, grain yield, nitrogen and phosphorus content in grain and fodder, nitrogen and phosphorus uptake by grain, protein content in grain and protein yield were found significantly superior as compared to CSV 15 and SPV 1430. CSH 14 recorded significantly highest grain yield over CSV 15 and SPV 1430 which was 21.60 and 36.62 per cent higher, respectively while CSV 15 also recorded 12.35 per cent higher grain yield over SPV 1430.

The wider crop geometry of 45 x 15 cm (1.50 lac plants ha⁻¹) produced significantly higher plant height and dry matter accumulation at various growth stages, took minimum days to bloom and maturity, higher in panicle length, total weight and grain weight per panicle, grains per panicle, test weight, grain yield, harvest index, nitrogen and phosphorus content in grain and fodder at harvest, nitrogen and phosphorus uptake by grain and total uptake by the sorghum crop, protein content and yield, net returns (Rs. 24292 ha⁻¹) and B:C ratio (3.03) as compared to 45 x 10 and 30 x 10 cm crop geometries (2.20 and 3.30 lac plants ha⁻¹, respectively). The crop geometry 45 x 15 cm recorded significantly higher grain yield as compared to 45 x 10 and 30 x 10 cm and recorded per cent higher to the tune of 14.83 and 65.07, respectively. While, crop geometry 30 x 10 cm recorded significantly higher dry fodder yield (129.46 q ha⁻¹) which was 23.67 and 5.75 per cent higher over 1.50 and 2.20 lac plants ha⁻¹.

The application of increasing levels of fertility from 50 to 125 % RDF significantly increased plant height and dry matter accumulation at various stages of crop growth, minimum days to 50 per cent bloom and maturity, and yield attributes viz., panicle length, weight and grain weight panicle⁻¹, grains panicle⁻¹ and test weight. Grain yield and harvest index of sorghum significantly increased with fertility levels and reported maximum with 100% RDF (39.16 q ha⁻¹ and 24.31 %). Whereas application of 125% RDF significantly recorded highest fodder (131.80 q ha⁻¹) and biological yield (171.30 q ha⁻¹) over rest of the fertility levels. However, N and P content and uptake at harvest in grain and fodder and their total uptake, protein content and protein yield increased significantly upto 125% RDF. The increasing levels of fertility from 50 to 125% RDF significantly increased the available nitrogen, phosphorus and potassium content in soil after the harvest of sorghum crop. Highest net returns (Rs. 24875 ha⁻¹) and B:C ratio (3.00) was recorded under 100% RDF

which was found at par to 125% RDF and significantly superior over 50 and 75% RDF, respectively.

The interaction effect of genotypes and fertility levels was found significant for plant height at 60 and 90 DAS and at harvest, dry matter accumulation per plant at 60 DAS and at harvest, grain yield, N content in grain and P content in fodder at harvest, N uptake by grain and total uptake by the crop, P uptake by grain, protein content and protein yield by grain. Further, interaction effect of genotypes and plant geometry was found significant for phosphorus content in fodder, nitrogen uptake by grain and total nitrogen uptake by the crop at harvest, phosphorus uptake by grain and protein yield at harvest.

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1. INTRODUCTION

In the recent years, agricultural production system of India is confronting for maintaining sustained growth to achieve food and nutritional security as well as to avoid ecological degradation of natural resource on account of their continuous over exploitation. Since very little scope exists for horizontal growth, the only alternative seems by achieving vertical growth through increasing the productivity of the crops. Now the genetic gains are fading away and further increase in productivity can be achieved only through appropriate production technologies.

Sorghum, the third important cereal crop in the country after rice and wheat is extensively grown on an area of 10.40m ha in the country and the annual production of about 8.86 million tonnes shares approximately 7.2 per cent of the cereal production in the country (India, 2002) considering the fact that sorghum is predominantly grown in rainfed areas of semiarid regions occupying 44 m ha in world and producing 69 mt of grain with an average productivity of about 1463 kg ha⁻¹ (NRCS, 2000). The contribution of sorghum towards overall economy of these regions assumes greater significance. This is well reflected with the belief that density of rainfed agriculture in India is closely linked with advancement in production and productivity of sorghum (Tandon and Kanwar, 1984) reduction probably on account of shift in food habit and economic prosperity of rural masses, as its area declined from 17.98 mha to 13.24mha within a span of three decades. On the other hand due to higher potential, wider adaptability and better nutritional quality, its use as industrial raw material, feed (poultry) and fodder (cattle) is increasing. It has been estimated that dry fodder availability in the western region is only 91.35 mt against requirement of 156.47 mt which accounts for deficit of 65.12 mt (Pandey, 1995).

In Rajasthan, sorghum occupies an area of about 6.15 lakh ha with annual production of 2.54 lakh tonnes and the productivity being 414 kg ha⁻¹, which is extremely low (Vital Statistics, 2001-02). Sorghum is not only an important crop of state but of Agro-climatic Zone – IV a “Sub-humid Southern Plain and Aravali Hills” too, where in, it is cultivated over an area of about 12430 ha with annual production of 7191 tonnes and productivity being 579 kg ha⁻¹, which is considerably low (Vital Statistics, 2001-02). The reason for low productivity of this crop in this zone seems to be non-adoption of proper agro-techniques like improper and inadequate nutrient

supply, optimum plant geometry and suitable genotypes. However, the production can be increased by adopting improved technology, package including suitable genotypes, optimum plant geometry and appropriate fertilization. Considering these facts, research efforts have been made to achieve substantial increase in sorghum productivity through better genotypes development and dissemination of appropriate production technology. But still a wide gap exists between realisable yield and yield obtained at the farmers end. This is clearly evident from yield level of 5-6 t ha⁻¹ under research plots and 3-4 t ha⁻¹ on farmers field against the all India average of 0.32 t ha⁻¹ (Tandon and Kanwar, 1984). These facts clearly suggest urgent need for renewed research efforts for development of location specific technology not only in traditional sorghum growing belt but also in areas where this crop has shown good potential. The availability of high yield and fertilizer responsive varieties of sorghum during the same period injected new enthusiasm in fertilizer research. Therefore, identification of superior sorghum genotypes and development of location specific production technology offers an excellent opportunity to provide stable food for human as well as to bridge the deficit of fodder for better nutrition of bovine population. Considering these facts, research efforts have been initiated and recently new genotypes of sorghum CSV15, SPV 1430 and CSH 14 have been released. The yield potential of a crop is dependent on its inherent capabilities along with extent to which it is being exploited through appropriate agro-techniques. Thus, there is need to work out optimum combination of different growth factors so as to exploit potential of these varieties under prevailing conditions (Sub-humid Southern Plain and Aravali Hills-Agroclimatic Zone IV a of Rajasthan).

While the need for suitable genotypes is desirable, working out optimum plant geometry to obtain appropriate plant population is equally important. Many times improper crop stand in the field leads either to overcrowding or gappiness, which ultimately tells upon the growth and productivity of the crop. Therefore, it would be in the fitness of the things to precisely workout the optimum plant geometry for obtaining maximum grain and fodder yield.

Amongst growth factors, adequate chemical fertilizers specially, nitrogen and phosphorus, is considered to be of prime importance due to its profound impact on various aspects of growth and development, hence, productivity of the crop. Balanced use of fertilizers has played a key role in the modernization of Indian agriculture and in making the country self sufficient in food grain production. It is estimated that

almost 40 per cent of the total food grain out put can be directly attributed to fertilizer use. Variable inputs like nitrogen and phosphorus fertilization, nutrient availability, nutrient uptake and their efficient utilization should be evaluated and optimized for realizing higher grain and fodder yield. In this connection N and P nutrition plays a vital role in maximizing the grain and fodder yields as majority of Indian soils are low in N and P (Tandon and Pratap Narayan, 1990) and medium in potassium.

It is a well established fact since long that amongst the nutrients, nitrogen plays an important role in the growth and development of crop plants. Nitrogen is indispensable for increasing crop production as it being constituents of protoplasm and chlorophyll is associated with the activity of living cells, coupled with greater volatilization and leaching losses. Nitrogen is removed by plants in comparatively larger amounts and most of the Indian soils are deficient in nitrogen. In spite of this, farmers seldom apply full dose of nitrogen to sorghum crop due to high cost of fertilizers, because marginal and small farmers have very meagre financial resources to purchase the required quantity of fertilizers. Sorghum being a *kharif* crop, so farmers do not want to bear the risk of applying any chemical fertilizers at its full recommended dose. Since optimum dose of nitrogen is dependent on several factors like soils, crop, environment and crop growing situations, it necessitates to work out economic and viable dose under prevailing conditions.

It is well established fact that after nitrogen, phosphorus nutrition plays a key role in plant metabolism. It is most essential for all living creatures for their growth and development. Besides its involvement in various biochemical process, it ensures transfer and storage of energy as ADP and ATP, permits conversation and transmission of genetic characters, as it is a constituent of RNA and DNA. The effectiveness of phosphorus nutrition is dependent on various factors, namely soil type, agroclimatic conditions, crop and its growing habits etc. Though sorghum has extensive root system and explores a large volume of soil, it shows a greater response to applied phosphorus. Intensive investigations indicated that the effects of phosphorus either alone or in combination with other nutrients, vary markedly. Hence considering these factors, investigation is needed to recommend optimum dose.

There have been a large variation in the optimum level of nitrogen and phosphorus recommendation for high yielding sorghum genotypes. Use of inadequate quantities of fertilizers is one of the major constraints in exploiting yield potentials of sorghum varieties. Sorghum responds differently under different agroclimatic

conditions and different sorghum cultivars having varying magnitudes of response to N & P. The development of elite genotype is a continuous process and currently many genotypes of different maturity groups are evolved, therefore, it is important to assess the magnitude of their response to fertility levels and simultaneously find out the production potential.

The present field experiment entitled “Effect of plant geometry and fertility levels on productivity of various elite sorghum (*Sorghum bicolor* L. Moench) genotypes” was conducted during *kharif* seasons of 2003 and 2004 with the following objectives :

- (i) To assess the relative performance of different promising genotypes and to identify a suitable genotype for the Zone IV a.
- (ii) To work out optimum plant geometry for higher production.
- (iii) To study the effect of genotypes, plant geometry and fertility levels on productivity and nutritional status of sorghum.

2. REVIEW OF LITERATURE

In this chapter an attempt has been made to review the research findings on the effect of plant geometry and fertility levels on productivity of various elite sorghum (*Sorghum bicolor* L. Moench) genotypes. The available research information on effect of plant geometry on sorghum crop is meagre. Hence, to elucidate the role of plant geometry on various aspects of the crops, researches on row spacing of other crop i.e. maize has also been incorporated.

2.1 EFFECT OF GENOTYPES

2.1.1 Growth and yield attributes

At Udaipur (Rajasthan), results of a field experiment revealed that SPV 946 significantly recorded higher plant height, dry matter accumulation per plant, total weight and grain weight of 10 earheads and test weight over SPV 462. Similarly, CSH 9 also recorded significantly higher values of growth characters and yield attributes than CSH 13R (Gupta and Mali, 1998). An experiment conducted at Udaipur reveal that among 15 genotypes tested, genotype CSV 15 recorded significantly higher plant height (258.15 cm) which was at par with SPV 1022, SPV 1328, SPH 792, SPH 840, SPH 960 and SPH 976, while hybrid SPH 966 recorded the minimum days of bloom (59 days), CSH 14 recorded the highest weight and number of grains per panicle, whereas SPH 960 recorded the highest test weight (28.37 g), (Mali *et al.*, 2000).

Sumeriya (2000) at Udaipur reported that sorghum cultivar CSH 9, CSH 14, CSH 15 and CSH 16 registered plant height (189.6, 195.0, 240.5 and 218.5 cm) and 1000 grain weight of 26.81, 27.45, 26.71 and 27.46 g, respectively. Findings of an experiment conducted at Udaipur showed that genotype SU 1 recorded maximum plant height (340.41 cm) over MASS/9602, MASS/9205, CSV 15 and SPV 1477 which was significantly superior to the magnitude of 68.75 and 57.94 per cent over MASS/9602 and CSV 15, respectively. In terms of test weight, genotype SPV 1355 was on top (27.50 g) and significantly superior over other genotypes and closely followed by MASS/9603, SPV 1478 and SPV 1484 (Annual Report, 2000-01). Bishnoi (2002) reported that CSV 15 recorded significantly higher plant height and number of grains per earhead over CSV 10.

Dixit *et al.* (2002) while working at Pantnagar to study the performance of 15 sorghum genotypes and results reported that genotype SPH 960 recorded significantly higher Panicle length (27.50 cm), panicle diameter (9.74 cm), panicle weight (77.09), grain weight per panicle (35.60 g) and number of grain per panicle (1494) which was significantly higher over CSH 9 and CSH 14. At Udaipur, sorghum genotypes namely CSV 15, SPV 1430, CSH 16, SPH 837, SPH 964, SPH 981, SPH 1037 and SPH 1065 were tested, the results revealed that genotype SPH 837 proved best and bloomed in minimum days (58 days) followed by SPH 1037, SPH 964, SPH 1037 recorded the 5.6 per cent higher in test weight, CSV 15 recorded the highest plant height (Mali *et al.*, 2002). According to Singh and Sumeriya (2002) sorghum genotype SPV 1489 recorded significantly minimum days to flowering. While, CSH 16, recorded highest test weight (32.39 g), CSV 15 and SPV 1472 recorded highest plant height (235 cm).

At Rahuri (Maharashtra), Wani *et al.* (2002) reported that sorghum genotype CSV 216 recorded significantly higher plant height, dry matter accumulation per plant grain weight per panicle and test weight over M-35-1 and RSLG. Bishnoi *et al.* (2004) at Udaipur reported that sorghum variety CSV 15 recorded significantly higher in plant height and grains / earhead over CSV 10 to the magnitude of 10.55 and 13.61 per cent, respectively. Rao *et al.* (2004) at Pali-Marwar (Rajasthan) reported that sorghum cultivar CSV-15 was found at par with local white in plant height. An experiment was laid out at Udaipur to test six sorghum genotypes *viz.*, SPH 1342, SPH 1347, CSH 9, CSH 14, CSH 16 and CSH 13, results revealed that genotype CSH 13 recorded significantly higher plant height (310.08 cm), and green weight of 8 plants (2789 g) while, CSH 16 recorded significantly minimum days to flowering (56 days), total weight and grain weight of 5 panicles, CSH 13 recorded significantly higher test weight. Whereas, CSH 16 recorded significantly higher in number of grains per panicle over rest of the genotypes tested (Singh *et al.*, 2004).

At Udaipur (Rajasthan), Singh and Sumeriya (2004) revealed that among sorghum cultivars GJ-39 recorded significantly minimum days to flowering, MP chari recorded highest plant height (331 cm) and SU 658 recorded higher test weight compared to other genotypes. An experiment conducted at Udaipur, results revealed that hybrid SPH 1290 proved minimum days to flowering, SPV 1616 recorded significantly higher in plant height (288.78 cm), CSH 16 recorded significantly higher in total weight (595.22 g) and grain weight (442.67 g) of 5 panicles and test weight (31.17) which was significantly higher over CSH 14 and CSV 15 (Annual Report,

2004-05). Dixit *et al.* (2005) while working at Pantangar revealed that genotype 960 recorded significantly better growth and higher yield attributes *viz.*, panicle length, panicle diameter, panicle weight and grains / panicle compared to the other genotypes tested. Genotype SPH 792 recorded significantly higher in plant height compared to the other genotypes tested. Findings of an experiment conducted at Udaipur revealed that SPH 837 registered minimum days to 50 percent flowering, CSH 16 recorded maximum test weight and CSV 15 significantly noted maximum plant height over rest of genotypes tested (Sumeriya *et al.*, 2005). Findings of an experiment conducted at Udaipur revealed that among 8 genotypes tested, CSH 17 recorded significantly minimum days to 50 percent bloom, SPH 1467 recorded significantly higher in plant height, CSH 18 recorded significantly higher in total weight and grain weight of 5 panicles and SPH 1467 recorded higher in test weight over SPH 1476 and CSV 15 (Singh and Sumeriya, 2006).

2.1.2 Grain and fodder yield

At Udaipur sorghum genotypes *viz.*, SPV 775, SPV 881, SPV 678, SPV 462, SPH 468 and CSH 6 were tested and results revealed that sorghum hybrid SPH 468 proved best in terms of grain yield (33.25 q ha⁻¹) followed by SPV 881 (29.93 q ha⁻¹), SPV 775 (29.53 q ha⁻¹), SPV 678 (29.13 q ha⁻¹) and SPV462 (29.06 q ha⁻¹). The hybrid SPH 468 produced 3 per cent higher grain yield than CSH 6 which gave lowest grain yield (25.2 q ha⁻¹). Maximum fodder yield (106.79 q ha⁻¹) was obtained with variety SPV 775 followed by SPV 462 (102.25 q ha⁻¹) and SPH 468 (101.01 q ha⁻¹). The variety CSH 6 produced the lowest fodder yield (75.56 q ha⁻¹) (Annual Report, 1990- 91).

Santhi *et al.* (1991) observed that CO-25 sorghum cultivar was better than other cultivars like AVSVAT 16 and A 573. To evaluate the performance of sorghum genotypes a study was carried out at Udaipur. The test hybrid SPH 468 (CSH 14) significantly out yielded over the checks CSH 6 and CSH 9. On two years mean basis this entry produced grain yield (39.62 q ha⁻¹) and proved significantly superior to CSH 6 (23.42 q ha⁻¹). While, SPV 946 (81.17 q ha⁻¹) was also superior over SPV 475 (59.33 q ha⁻¹) in terms of fodder yield whereas, it was at par with SPV 938 (Annual Report, 1992-93).

According to Mahakulkar *et al.* (1992) sorghum hybrid SPH 468 produced significantly higher grain yield over SPH 388 and SPV 669. While, improved variety

SPV 669 recorded significantly higher stover yield than SPH 468 and SPH 388. At Akola, Dharwad, Indore, Mauranipur, Parbhani and Surat performance of four test genotypes viz., PJH 55, PJH 58 (hybrid) and SPV 1025 and SPV 1041 (varieties) along with checks CSH 9, SPV 475 was evaluated. CSH 9 registered its clear superiority in grain yield over PJ H55 at majority of locations and was at par at Indore and Mauranipur. At majority of locations CSH 9 was either superior or at par with PJH 58. However, PJH 58 registered higher grain yield at Mauranipur and Surat. Variety SPV 1025 was superior to SPV 475 in grain yield at Parbhani and Surat and found at par at Akola, Dharwad and Mauranipur. While, SPV 475 was superior at Pantnagar. SPV 1041 was superior in grain yield over SPV 475 only at Parbhani. PJH 58 was superior to CSH 9 in fodder production only at Surat and at other locations all three hybrids were at par. SPV 1025 was at par with SPV 475 at all locations while SPV 1041 was superior to SPV 475 in fodder production at Indore, Mauranipur and Parbhani. On an average SPV 1041 produced 30.1 q ha⁻¹ of dry matter over SPV 475. Test entries SPV 1025 and SPV1041 were at par with their check SPV 475 in grain yield. In case of fodder yield SPV 1041 recorded higher yield and on an average it was 13 q ha⁻¹ higher over SPV 475 (NRCS, 1993-94).

Findings of an experiment conducted during 1994-95 at All India Coordinated Sorghum Improvement Project, Udaipur revealed that CSV 15 (SPV 946) registered maximum fodder yield over check SPV 462 (77.06 q ha⁻¹) (Annual Report, 1994-95). Results of field experiment conducted at Udaipur revealed that SPV-946 significantly out yielded over SPV 462 in terms of grain (15.60 q/ha) and fodder yield (46.29 q/ha) by a margin of 76.87 and 22.16 per cent, respectively. It was also maintained its superiority over SPV 938 in terms of fodder yield. Similarly, CSH 9 brought about significant increase of 73.50 and 44.25 per cent in grain and fodder yield, respectively (Gupta and Mali, 1998).

Results of the experiment conducted at Udaipur showed that the inbred SPV 1333 significantly out yielded SPV 1328 though it was at par with CSV 15. As regard fodder yield SPV 102 (142.52 q ha⁻¹) proved superior to SPV 1328 (108.06 q ha⁻¹). The test hybrid SPH 960 significantly recorded higher grain yield (44.39 q ha⁻¹) over SPH 660, SPH 792 and SPH 815 amounting to increase of 22.62, 62.30 and 32.07 per cent, respectively (Annual Report, 1998-99). Experiment conducted at RCA, Udaipur revealed that mid early genotype SPV 1430 significantly out yielded the check CSV

15 by a magnitude of 34.26 and 20.89 per cent in terms of grain (30.18 q ha^{-1}) and fodder yield (124.6 q ha^{-1}), respectively (Annual Report, 1999-2000).

Findings of an experiment conducted at Udaipur revealed that among 15 genotypes tested, genotype SPH 960 recorded highest grain yield (44.39 q/ha) gross and net returns while ,CSV 15 recorded significantly higher fodder yield (152.22 q/ha) (Mali *et al.*, 2000). Sumeriya (2000) at Udaipur, reported that, among the different sorghum cultivars (CSH 9, CSH 14, CSV 15 and CSH 16), CSH 14 recorded significantly higher grain yield (42.52 q/ha), gross and net returns and B:C ratio, which was found at par with CSH 9 for all the above parameters. Variety CSV 15 recorded significantly higher in fodder yield (150.84 q/ha) over rest of the genotypes tested.

At Udaipur, sorghum genotypes *viz.*, CSV 15, SPV 1430, CSH 16, SPH 837, SPH 964, SPH 981, SPH 1037 and SPH 1065 were tried. Results revealed that genotype SPH 981 recorded the highest grain (38.05 q/ha) and fodder (187.30 q/ha) yield which was at par to SPH 837 in grain yield and 95.30 per cent higher than CSH 16 in grain yield. Genotype SPH 981 recorded significantly higher in fodder yield, gross returns, net returns and B:C over other genotypes tested and recorded 32.73, 30.08, 35.97 and 36.01 per cent, respectively higher over SPH 1065 (Annual Report 2000-2001).

Findings of experiment conducted at Udaipur revealed that genotype SPV 1472 significantly out yielded the check variety CSV 15 as well as hybrid CSH 6 checks to the tune of 37.37 and 27.08 per cent in terms of grain yield (45.14 q ha^{-1}). Whereas, in case of fodder yield CSV 15 was found superior over rest of genotypes tested (Singh and Sumeriya, 2002). Gampawar *et al.* (2002) observed that improved Ramkel produced the highest green fodder yield (350.02 q ha^{-1}) over NJ.156 (338.96), Nilwa (302.24) and MP Chari (292.77).

Bishnoi *et al.* (2004) at Udaipur revealed that variety CSV 15 was significantly higher in grain, green and dry fodder yield over CSV 10 to the magnitude of 23.35, 14.54 and 64.50 per cent, respectively. At Udaipur, performance of 5 genotypes *viz.*, PJH 58, CSH 9, SPV 1025, SPV 1041 and CSV 15 were evaluated, genotype CSH 9 registered its clear superiority in grain yield over SPV 1025, SPV 1041 and CSV 15 to the magnitude of 20.27, 46.57 and 15.91 per cent, respectively. Whereas, SPV 1041 registered its superiority in fodder yield over rest of the genotypes by a margin of 42.09, 24.48, 34.95 and 2.71 per cent, over PJH 58,

CSH 9, SPV 1029 and CSV 15, respectively. CSH 9 recorded significantly higher in gross and net returns over rest of the genotypes tested (Dashora *et al.*, 2004).

Singh and Sumeriya (2004) at Udaipur, revealed that among four genotypes tested SU 658 recorded significantly higher grain yield while CSV 15 produced significantly higher fodder yield as compared to other genotypes. Findings of an experiment conducted at Udaipur indicate that genotype CSH 16 recorded significantly higher grain yield (45.53 q/ha) whereas CSH 13 obtained significantly higher fodder yield (219.62 q/ha) over rest of genotypes tested (Singh *et al.*, 2004). Dixit *et al.* (2005), studied that genotype SPH 960 recorded highest grain yield (46.50 q/ha) and SPH 792 recorded significantly higher fodder yield compared to all the genotypes tested. The corresponding increases were by 41.34 and 35.57 and 19.40 and 50.30 per cent, respectively higher over CSV 15 and CSH 9 in grain and fodder yield. At Udaipur, among hybrids CSH 18 and among varieties SPV 1686 recorded significantly higher grain yield which was 20.29 and 12.45 per cent higher over CSV 15, respectively. With regards to fodder yield, CSV 15 maintained its superiority over all the genotypes and recorded 10.19 and 21.15 per cent, respectively higher over SPH 1467 and CSH 17, respectively (Singh and Sumeriya, 20006).

2.1.3 Biochemical Composition

Raj (1985) reported that hybrid forage sorghum AS-IS had significantly higher content and uptake of N, P, K, Ca, Mg, Fe, Zn and Cu than variety M.P. chari but Mn content of sorghum was not altered significantly by genotypes. At Udaipur, results of a field experiment indicated that significantly higher uptake of nitrogen by grain, fodder and total nitrogen by the crop were recorded under SPV 946 over SPV 462 (Gupta and Mali, 1998). At Udaipur, Khatik *et al.* (1999) reported that genotype SPV 475 recorded significantly higher N, P, Zn, Mn and Cu content in grain and stover which was significantly higher over rest of the genotypes. The uptake of major nutrients in grain was significantly higher in hybrid MLSH 14 and variety SPV 475 and while in stover it was registered with genotypes CSH 9 and SPV 1231.

Rana *et al.* (2000) at Palampur (Himachal Pradesh), revealed that genotype PJH 58 recorded highest total uptake of N, P and K followed by PJH 55, while genotype SPV 1025 recorded lowest uptake of N, P and K. Bishnoi *et al.* (2003) at Udaipur noted that high yielding variety CSV 15 recorded significantly higher nitrogen concentration in fodder and N uptake by grain, fodder and total uptake to the

magnitude of 24.24, 70.50 and 42.86 per cent over CSV 10. Dixit *et al.* (2005) at Pantnagar reported that, among the 15 sorghum genotypes tested, genotype SPH 960 recorded significantly higher N and P uptake and SPH 792 recorded the highest K uptake over rest of the genotypes tested. The corresponding increases were by 16.39 and 29.47, 14.42 and 30.42 and 17.40 and 43.46 per cent, over CSV 15 and CSH 9, respectively.

Findings of experiment conducted at Udaipur (Rajasthan), Sumeriya *et al.* (2005) revealed that among 8 genotypes tested, genotype SPH 837 contained significantly higher nitrogen content in grain and fodder while, genotype SPH 981 recorded significantly higher nitrogen uptake by grain, fodder and total uptake by a margin of 93.88, 97.26 and 96.23 per cent over CSV 15, respectively.

2.2 EFFECT OF PLANT GEOMETRY / PLANT POPULATION / PLANT DENSITY

2.2.1 Growth and yield attributes

To study the physiological basis of grain yield compensation at low plant density, Subramanian and Rao (1987) conducted two field trials on dry land sorghum. The effects of plant density on leaf area development, dry matter partitioning during grain filling and grain yield components were studied. Compensation was more in the reproductive organs than vegetative organs. At low density of plants, more panicles per plant at anthesis ensured greater sink capacity thus increased both the number of grain per panicle and the grain weight. The plants with higher proportion of flag leaf area in the total leaf area and more efficient leaves (more grains per unit leaf area), higher sink intensity during early grains growth and greater mobilization of assimilate from the stem during grains filling contributed to the production of more grain than those produced at high plant density.

Gupta and Mali (1998) at Udaipur revealed that plant density significantly influenced various growth characters and yield attributes. There was a reduction in these parameters, when plant density was increased from 1.5 to 1.8 lakh plants ha⁻¹. Whereas, there was no significant reduction in growth and yield parameters when density was further raised to 2.1 lakh plants ha⁻¹. An experiment was laid out at Udaipur to evaluate the performance of various plant geometry (plant density *viz.*, 1.5, 1.8, 2.1 and 2.4 lakh plants ha⁻¹). Plant density at 45 x 15 cm comprising of 1.50 lakh plants ha⁻¹ recorded the significantly higher in plant height at 60 and 90 DAS and at

harvest, dry matter accumulation plant⁻¹ at 30, 60 and 90 DAS and at harvest, green leaves per plant and test weight over 2.1 and 2.4 lakh plants ha⁻¹ (Poonia *et al.*, 1999).

Kaushik (2000) at Udaipur reported that spacings had no significant influence on growth and yield contributing parameters. Findings of experiment conducted at All India Coordinated Sorghum Improvement Project, Udaipur showed that plant geometry 45 x 12-15 cm (1.50 lakh plants ha⁻¹) recorded the highest grain weight of five panicles and number of grains per panicle by a margin of 6.94 and 8.05 per cent over 3.00 lakh plants ha⁻¹ (30 x 10 cm), respectively (Annual Report, 2000-2001). Findings of experiment conducted at Udaipur by Bishnoi (2002) revealed that plant population was significantly affected various growth characters and yield attributes. Significant reduction in number of grains per earhead was observed when plant population was raised from 150,000 to 333,000 plants ha⁻¹ to the magnitude of 6.42 and 28.07 per cent, respectively over 222,000 and 333,000 plant ha⁻¹.

An another experiment was laid out at Udaipur during 2002-03 and 2003-04 to evaluate the performance of varying plant geometry/plant density *viz.*, 45 x 15 cm, 45 x 10 cm and 30 x 12 cm (150,000, 220,000 and 290,000 plants ha⁻¹, respectively). Plant density 45 x 10 cm comprising of 220,000 plants ha⁻¹ recorded the significantly maximum total weight and grain weight of 5 panicles over 150,000 and 290,000 plants ha⁻¹ (Annual Report, 2003-04).

2.2.2 Fodder and grain yield

Schatz *et al.* (1990) conducted field trials at Carrington in 1986-87 and Prosper in 1986, in which sorghum was sown at 15 cm and 76 cm between row spacings and thinned plant populations of 74,000-2,22,000 plants per hectare. Grain yields were the highest at narrow row spacing. Research findings of Wade and Douglas (1990) revealed that the highest grain yield was obtained with plant density of 50,000-1,00,000 plants per hectare under rainfed conditions.

At Texas Jones *et al.* (1991) working with rainfed sorghum hybrid DK-46 reported that an inter row spacing of 30 or 60 inches with a plant population of 24,000 per acre produced highest yields. However, a wide range in plant population (16,000 to 34,000 plants per acre) grain yield as not decreased by more than 5.0 per cent due to population effects. The best sorghum production strategy with DK-46 was to use 30 inches rows sown at 31,000 to 35,000 seeds per acre. Ogunlella (1991) tried the plant density levels of 33,300, 50,000 or 60,000 plants per hectare and determined dry

matter yields at 12, 15, 18, 21 and 24 weeks after sowing. He concluded that plant density for dry matter production was 33,300 plants per hectare.

While Dashora *et al.* (1992) working at Udaipur, reported that grain and fodder yields were higher in variety CSH-9 with increased rate of nitrogen application and sowing before monsoon with 1,80,000 plants per hectare. To exploit the full potential of dual purpose genotypes for fodder production with least reduction in grain yield a study was made at multilocations in which four plant densities viz. 1.5, 1.8, 2.1 and 2.4 lacs ha⁻¹ were tried. Increased plant density substantially increased fodder yield while there was no reduction in grain yield. It was inferred from the data that higher fodder production could be obtained by increasing plant population upto 2.1 lac ha⁻¹ without any adverse effect on grain yield (Annual Report, 1994-95).

At Udaipur Gupta (1997) revealed that plant density significantly influenced grain and fodder yield. Marginal reduction in grain yield (2.21 q ha⁻¹) recorded when density was raised from 1.8 to 2.1 lac plants ha⁻¹ but there was quantum increase of 8.33 q ha⁻¹ in fodder yield at 2.1 lac plants ha⁻¹. The reduction in grain yield was 15.99 and 26.94 per cent over 2.1 and 2.4 lac plants ha⁻¹, respectively. Poonia (1997) opined that plant density had significant effect on grain and fodder yield of sorghum genotypes. Plant density 150,000 plants ha⁻¹ recorded significantly higher grain yield and harvest index over 210,000 and 240,000 to the magnitude of 21.93 and 48.92 and 53.61 and 43.81 per cent. Marginal reduction in grain yield (2.54 q ha⁻¹) was recorded when density was raised from 1.8 to 2.1 lac plants ha⁻¹ but there was quantum jump in fodder yield (5.87 q ha⁻¹ at 2.1 lac plants ha⁻¹).

Findings of experiment conducted at Udaipur to evaluate the performance of various row spacing viz., 40 cm, 60 cm and 80 cm on grain and fodder yield of sorghum variety CSV 10. The maximum grain yield was obtained with 60 cm row spacing (23.48 q ha⁻¹) which was 3.03 and 11.22 per cent higher over 80 and 40 cm row spacing. There was no significant difference in yield due to 60 and 80 cm row spacing. The fodder yield was significantly increased with 40 cm row spacing which was significantly superior over other row spacing representing 9.02 and 9.04 per cent higher over 60 and 80 cm spacing (Kaushik, 2000). Findings of an experiment conducted at Udaipur, showed that maximum grain yield recorded with 1.50 lakh plants ha⁻¹ which registered significantly higher yield by 17.32 per cent over double plant population (3.00 lakh plants ha⁻¹). As regard to dry fodder yield of 181.13 q ha⁻¹

which was significantly higher by 13.75 per cent over normal plant population i.e. 1.50 lac plants ha⁻¹ (Annual Report, 2000-2001).

Bishnoi (2002) at Udaipur studied that plant population significantly affected crop yields. Marginal reduction in grain yield (3.40 q ha⁻¹) was noted when plant population was raised from 150,000 to 222,000 plants ha⁻¹ but there was a quantum increase of 22.52 q ha⁻¹ in fodder yield at 222,000 plants ha⁻¹. An experiment was laid out at Udaipur to evaluate the performance of varying plant geometry (plant density) viz., 45 x 15, 45 x 10 and 30 x 12 cm (150,000, 220,000 and 290,000 plants ha⁻¹, respectively) on crop yield. As regards to grain yield, 220,000 plants ha⁻¹ produced significantly higher grain yield (50.33 q ha⁻¹) over 150,000 and 290,000 plants ha⁻¹ amounting to increases of 11.97 and 13.53 per cent, respectively. In case of fodder yield, highest plant density (290,000 plants ha⁻¹) proved significantly superior over both the lower densities to the magnitude of 14.45 and 10.03 per cent over 1.50 and 2.20 lakh plants ha⁻¹, respectively. (Annual Report, 2003-04).

Raskar *et al.* (2006) at Rahuri (Maharashtra) reported that the grain yield of rabi sorghum was significantly higher at higher plant density of 1.85 lac plants ha⁻¹ than grain yield recorded at lower plant density of 1.11 and 1.48 lac plants, however, it was at par with 1.66 lac plants ha⁻¹. The grain yield at 1.85 lac plants ha⁻¹ was higher by 19.07 and 6.62 per cent, respectively over 1.11 and 1.48 lac plants ha⁻¹. Similarly, 1.85 lac plants ha⁻¹ accounted significantly higher yield of fodder over rest of plant densities.

2.2.3 Nutrient content and uptake

An experiment conducted at Udaipur shows that nitrogen content in grain as well as dry fodder was higher in plant population of 1,50,000 plants ha⁻¹ than 3.00 lakh plants ha⁻¹. Whereas, nitrogen uptake by grain and total nitrogen uptake by crop at 1.50 lac plants ha⁻¹ registered significantly higher by a magnitude of 40.94, 2nd 4.73 per cent, respectively over 3.00 lakh plants ha⁻¹. The higher protein content in grain as well as in fodder recorded with 1.50 lakh plants ha⁻¹ over plant population of 3.0 lakh plants ha⁻¹ (Annual Report, 2000-2001).

Bishnoi *et al.* (2003) conducted an experiment at Udaipur with sorghum cultivars CSV 15 and CSV 10 which gave highest nitrogen content in grain and fodder at 150,000 plants ha⁻¹ followed by 222,000 and 333,000 plants ha⁻¹. With regards to its uptake by grain, fodder and total uptake by crop at 150,000 plants ha⁻¹

recorded significantly higher nitrogen uptake by grain. While 222,000 plants ha⁻¹ recorded higher nitrogen uptake by fodder and 150,000 plants ha⁻¹ recorded maximum total nitrogen uptake by crop.

Studies made by Kaushik and Shaktawat (2005) at Udaipur revealed that crop sown at row spacing 60 cm recorded highest nitrogen uptake by grain and total nitrogen uptake by crop. Whereas 40 cm row spacing recorded maximum nitrogen uptake by stover. With regards to phosphorus uptake, 60 cm row spacing recorded significantly higher phosphorus uptake by grain than rest of the row spacings tested.

2.3 EFFECT OF FERTILITY LEVELS

Nitrogen and phosphorus are the most essential elements required for growth and development of sorghum. Deficiencies of these elements are considered to be widespread in the soils of Indian semi-arid tropics and of practical importance for improving sorghum yield (Rao and Das, 1982). The response of sorghum to N and P application have been extensively reported (Hirpara *et al.*, 1992; Singh *et al.*, 1996; Patidar 1999 and Jat, 1999).

2.3.1 Plant height

Chaudhary and Khade (1991) observed an increase in plant height with application of NPK fertilizers. A significant improvement in plant height of sorghum was recorded with application of nitrogen (Kumar, 1993; Deshmukh *et al.*, 1996; Sharma, 1997; Barik *et al.*, 1998; Jat, 1999; Kaushik, 2000 and Bhisoi *et al.*, 2003). On the other hand, the plant height was not influenced either by nitrogen or by phosphorus application (Hirpara *et al.*, 1992). While Meghwanshi (1992) observed significant influence of both nitrogen and phosphorus application on plant height of sorghum. The increase in plant height due to NPK fertilization may be due to increase in cell division (Rajput *et al.*, 1993).

Findings of experiments conducted at various locations reported that application of 100:50 kg N:P₂O₅ ha⁻¹ recorded significantly higher plant height over 40:20 and 20:10 by 7.78 and 10.70 per cent, respectively (NRCS, 1993-94). However, Jadhav (1994) observed a significant increase in plant height with full dose of fertilizers (75 kg N + 50 kg P₂O₅ ha⁻¹) as compared to half dose of fertilizers (37.5 kg N + 25 kg P₂O₅ ha⁻¹). While the studies of Mohammed *et al.* (1994) revealed that fertility variation treatments did not influence the plant height of sorghum on alfisol

of Southern Telangana region of Andhra Pradesh. While working on the same line at Pantnagar (UP), Singh *et al.* (1996) observed that plant height of sorghum increased by 10.29 per cent with 100 kg N + 50 kg P₂O₅ ha⁻¹ over 80 kg N + 40 kg P₂O₅ ha⁻¹ under rainfed conditions.

Evaluation of sorghum genotypes for their response to different fertility levels at Akola, Coimbatore, Dharwad, Indore, Palem, Pantnagar, Parbhani, Surat and Udaipur revealed that application of 100:50 kg N:P₂O₅ ha⁻¹ recorded significantly higher plant height over 60:30, 40:20 and 20:10 kg N : P₂O₅ ha⁻¹. The increases were by 6.81 and 5.04 per cent over 20:10 and 40:20 kg N : P₂O₅ ha⁻¹, respectively (NRCS, 1996-97). Application of 40, 80 and 120 kg N ha⁻¹ increased plant height by 17.70, 26.87 and 28.59 per cent, respectively over no application. The highest plant height (178.38 cm) was recorded with 120 kg N ha⁻¹, which was found significantly superior over 0 and 40 kg N ha⁻¹ but at par with 80 kg N ha⁻¹ in response to increase in the plant height (Sharma, 1997).

Results of the experiments conducted at various locations i.e. at Akola, Coimbatore, Dharwad, Indore, Palem, Pantnagar, Parbhani, Surat and Udaipur to evaluate performance of sorghum genotypes at six fertility levels *viz.*, 0:0, 20:10, 40:20, 60:30, 80:40 and 100:50 kg N:P₂O₅ ha⁻¹ tried. Pooled data indicated that 100:50 kg N:P₂O₅ ha⁻¹ recorded significantly higher in plant height over rest of the levels (NRCS, 1997-98). At Udaipur, Poonia *et al.* (1999) reported that application of 80 kg N ha⁻¹ recorded significantly higher in plant height over 40 kg N ha⁻¹ and control at 60, 90 DAS and at harvest to the magnitude of 10.81 and 36.03, 10.20 and 39.91 and 4.93 and 15.28 per cent, respectively.

Significant increase in plant height by 7.80 and 6.56 per cent at 60 DAS and at harvest was recorded with the application of 80:40 kg N:P₂O₅ ha⁻¹ over 40:20 kg N:P₂O₅ ha⁻¹ (Mali *et al.*, 2000).

While at Udaipur, Singh and Sumeriya (2002) observed that application of 100 per cent recommended fertility level (80 kg N + 40 kg P₂O₅ ha⁻¹) significantly improved the plant height amounting to 6.69 per cent higher over control. Findings of Bishnoi *et al.* (2004) at Udaipur revealed that application of 100 kg N ha⁻¹ recorded 5.56 per cent higher plant height over 80 kg N ha⁻¹ and at par with higher level (120 kg N ha⁻¹). Plant growth parameters *viz.*, plant height was also significantly increased upto 100 percent RDF. Application of 100 percent recommended dose of fertilizers (80 kg N + 40 kg P₂O₅ ha⁻¹) recorded significantly higher plant height over 50 percent

RDF and control. The corresponding increases were by 4.46 and 10.10 per cent (Patidar and Mali, 2004).

Dixit *et al.* (2005) opined that plant height increased significantly with the application of 80 + 40 kg N + P₂O₅ ha⁻¹ (100 percent RDF) over 50 percent RDF. The magnitude of increase recorded was of the order of 6.53 per cent with 100 percent RDF. At Udaipur, Singh and Sumeriya (2005) reported that application of 80 kg N ha⁻¹ recorded significantly higher in plant height over 40 kg N and control. The magnitude of increase was of the order of 3.13 and 6.51 per cent. At Udaipur application of 80 kg N + 40 kg P₂O₅ ha⁻¹ recorded significantly higher in plant height over 50 percent RDF and control. The corresponding increases were by 3.26 and 5.01 per cent, respectively. However, 50 percent RDF was also found significantly superior over control (Singh and Sumeriya, 2006).

2.3.2 Days to flowering

Phosphorus application significantly reduced days to flowering and physiological maturity on vertisol in Andhra Pradesh (Sahrawat *et al.*, 1995). Multilocation trials conducted with dual purpose elite sorghum genotypes resulted significant reduction in days to bloom under the influence of 80:40 and 100:50 kg N:P₂O₅ ha⁻¹ over control (NRCS 1997-98 and NRCS 1998-99). Physiological effect of nitrogen on early maturity was attributed to the development of leaves to the full potential, which resulted in accelerated photosynthesis, consequently the reproductive phase started earlier in hybrid sorghum. Number of days to attain 50 per cent flowering was significantly reduced with high N fertilization (120 kg N ha⁻¹) over nitrogen application at 60 kg N ha⁻¹ (Poonia, 1997). A significant reduction in days to bloom with increasing levels of nitrogen was noted (Gupta, 1997; Sharma, 1997; Dashora, 1998; Kaushik, 2000; Bishnoi, 2002 and Singh and Sumeriya, 2005). At Udaipur, Sumeriya *et al.* (2005) reported that application of 100 percent RDF recorded significantly reduced in days to flowering over 50 per cent RDF and control. The corresponding reduction was 2.12 and 4.51 per cent.

2.3.3 Photosynthetic parameters

At Junagarh application of 120 kg N ha⁻¹ profoundly increased LAI at harvest by 43.3 per cent over control (Hirpara *et al.*, 1992). Studies conducted at Udaipur revealed that application of 80 kg N ha⁻¹ registered significantly higher LAI by 7.14

and 15.38 per cent over 40 kg N ha⁻¹ and control, respectively (Kumawat and Bansal, 1996). Dashora (1998) observed that application of 120 kg N ha⁻¹ increased LAI at flowering by 14.5 per cent over 40 kg N ha⁻¹. Increase in LAI with N and P₂O₅ application was also reported by Singh *et al.* (1993). On the contrary, Mohammed *et al.* (1994) reported that fertility variation did not influence the number of leaves per plant. Whereas, Jadhav (1994) found an increase in number of leaves per plant by 5.03 per cent with the application of full dose of fertilizer as compared to half dose of fertilizer.

2.3.4 Dry matter accumulation

Nitrogen application increases dry matter accumulation in sorghum at all the stages of crop growth. In Gujarat, increasing rate of N from 40 to 120 kg ha⁻¹ enhanced biomass by 16 per cent (Raj and Patel, 1989). Positive response of nitrogen application up to 120 kg N ha⁻¹ on dry matter production was also reported by Malik *et al.* (1992); Kumar (1993); Dashora (1998) and Bishnoi *et al.* (2003). Palaniswamy *et al.* (1988) noted that contribution of leaves, stem and panicle weight towards total dry matter production at harvest was 10-15, 36-45 and 30-41 per cent in different cultivars.

Application of phosphorus reduced the lodging under heavy nitrogen application due to increase the strongness of stem and enhanced dry matter accumulation (Bishnoi and Singh, 1990). Chaudhary and Khade (1991) reported that application of NPK fertilizers increased dry matter production. The studies of Niranjana and Arya (1992) at Jhansi revealed that dry matter yield of sorghum was highest with application of 100 per cent recommended dose of N and P (60 kg N + 40 kg P₂O₅ ha⁻¹). At Udaipur, Meghwanshi (1992) opined that application of 80 kg N and 40 kg P₂O₅ per hectare significantly increased dry matter accumulation per plant. Das *et al.* (1996) also reported an increase in dry matter accumulation with application of phosphorus. Further, partitioning studies indicated that dry matter of leaves reached maximum at 56 DAS thereafter it remained constant, after that up to 15 days. After 70 days, the stem dry weight remained constant and most of dry weight increase was contributed to panicles. The contribution of leaves, stem and ear head dry weight towards total dry weight was 23, 41 and 36 per cent under unfertilized condition (N₀P₀) whereas under fertilized condition, it was 32, 18 and 50 per cent in respective parts. Increase in dry matter accumulation by 26.9 per cent with 100 kg N + 50 kg

P₂O₅ per hectare over 20 kg N + 10 kg P₂O₅ per hectare was reported by Singh *et al.* (1996).

2.3.5 Yield components

The grain yield of sorghum is highly associated with panicle weight that has maximum direct positive effect on yield (Jayaprakash *et al.*, 1997). The number of grains per panicle also contributes largely to the increase in grain yield (Bhosekar and Rajkelkar, 1990; Kumawat and Bansal, 1996; Kushwaha and Chandel, 1997 and Dashora, 1998). Kumawat and Bansal (1996) recorded 28, 43 and 10 per cent increase in grains per ear head, grain weight per ear head and test weight, respectively with application of 80 kg N ha⁻¹ over control. Ear head weight and grain yield per ear head was increased significantly with application of 80 kg N ha⁻¹. However, successive increase in N dose did not alter 1000 grain weight (Dashora, 1998).

Chaudhary and Khade (1991) noted an increase in panicle size and 1000 grain weight of sorghum hybrid CSH-5 with the application of increasing doses of NPK fertilizers. Improvement in yield attributes, viz., grain yield per plant and test weight were observed with application of N and P at Junagarh, Gujarat (Hirpara *et al.*, 1992). At Udaipur, Meghwanshi (1992) reported that yield attributes, viz., grains per panicle, grain weight per panicle and 1000 grain weight were improved significantly with application of 80 kg N and 40 kg P₂O₅ ha⁻¹. Jadhav (1994) reported that the important yield components of sorghum, viz., length of ear head, weight of ear head, weight of grain per ear head and 1000 grain weight were significantly increased with 75 kg N + 50 kg P₂O₅ ha⁻¹ compared to half of the recommended dose. Mohammed *et al.* (1994) concluded that the test weight improved from 18.7 to 22.6 g with increase in fertilizer rates from 20 + 10 to 80 kg N + 40 P₂O₅ ha⁻¹ and grain yield per plant significantly increased from 45.6 to 84.2 g in response of increasing fertilizer rates from 20 + 10 to 100 + 50 kg N + P₂O₅ ha⁻¹, whereas, panicle length was not influenced. At Pantnager, Singh *et al.* (1996) noted that application of 100 kg N + 50 kg P₂O₅ ha⁻¹ recorded 30.4, 14.5 and 22.3 per cent higher panicle weight per plant, grains per panicle and grain yield per plant, respectively, over 20 kg N + 10 kg P₂O₅ ha⁻¹ on light silty clay loam soil having medium available phosphorus.

Tripathi and Surajbhan (1995) also studied the effect of nitrogen fertilization in sorghum and observed that application of 60 kg N ha⁻¹ significantly increased the yield of sorghum and yield attributes like length and girth of panicle, grain weight per

panicle, number of grains per panicle and 1000-grain weight over control. At Udaipur, application of 80 kg N ha⁻¹ improved grains/earhead, grain weight/earhead and test weight by 28, 43 and 10 per cent, respectively over no nitrogen application (Kumawat and Bansal, 1996). Significant improvement in number, weight, girth and yield of panicle under influence of 120 kg N ha⁻¹ was observed by Kushwaha and Chandel (1997).

Dashora (1998) reported significant increase in dry matter production upto physiological maturity of variety CSV 15 with the application of 40 to 120 kg N ha⁻¹. Bishnoi *et al.* (2004) at Udaipur reported that application of 100 kg N ha⁻¹ recorded significantly higher number of grains / panicle over 80 kg N ha⁻¹ and the per cent increase was 24.65. Significant improvement in grain weight per panicle and test weight under the influence of 80 kg N ha⁻¹ was observed by Kaushik and Shaktawat (2005).

Application of 80 kg N + 40 kg P₂O₅ ha⁻¹ recorded significantly higher weight of earhead, number of grains per panicle and 1000-grain weight over 40:20 kg N:P₂O₅ ha⁻¹ to the magnitude of 7.44 and 5.28 per cent, respectively (Mali *et al.*, 2000). Patidar and Mali (2002) at Udaipur observed significant improvement in grains per earhead and 1000 grain weight by application of fertilizers. Application of 60 kg N + 30 kg P₂O₅ ha⁻¹ recorded the highest 1000 grain weight to the magnitude of 8.53 and 9.92 per cent over control during 1998 and 1999.

While, at Udaipur Singh and Sumeriya (2002) reported that application of 100 per cent RDF (80 kg + 40 kg N : P₂O₅ ha⁻¹) significantly improved the highest test weight amounting to the 4.78 per cent over control. Singh *et al.* (2004) at Udaipur (Rajasthan), revealed that application of 100 percent RDF (80 kg N + 40 kg P₂O₅ ha⁻¹) recorded significantly higher total weight and grain weight per panicle, test weight and grains per panicle over 10 t FYM ha⁻¹ and control. The magnitude of per cent increase were by 16.70 and 23.59 in weight per panicle, 14.60 and 32.83 grain weight per panicle, 3.67 and 8.05 test weight and 18.97 and 43.68 grains / panicle.

At Udaipur, Sumeriya *et al.* (2005), studied that application of 100 percent RDF (80 kg N + 40 kg P₂O₅ ha⁻¹) recorded significantly higher in test weight over 50 percent RDF (40 kg N + 20 kg P₂O₅ ha⁻¹) and control and amounting to increase 3.94 and 5.63 per cent, respectively. On clay loam soils of Udaipur, application of 100 percent RDF (80 kg N + 40 kg P₂O₅ ha⁻¹) obtained significantly higher weight of 5 panicles, grain weight of 5 panicles and test weight over 50 percent RDF (40 kg N +

20 kg P₂O₅ ha⁻¹) and control by a margin of 8.56 and 16.96, 5.30 and 16.15 and 3.27 and 6.05 per cent, respectively (Singh and Sumeriya, 2006).

2.3.6 Grain and fodder yield

In addition to the effect of fertilization on growth and development, its real effect is being reflected on the grain and fodder yield. The increase in grain and fodder yield of sorghum with application of 60 kg N ha⁻¹ was reported by Balasubramanian *et al.* (1993). Several other researchers (Dashora *et al.*, 1992; Singh *et al.*, 1993; Dashora and Porwal, 1994) obtained response up to 80 kg N ha⁻¹. Application of 80 kg N ha⁻¹ increased grain and fodder yield of sorghum by 56 and 40 per cent over control on clay loam soil at Udaipur (Kumawat and Bansal, 1996). Further, Poonia (1997) noted that crop fertilized with 80 kg N ha⁻¹ produced maximum grain yield (18.2 q ha⁻¹), while fodder yield was the highest (45.2 q ha⁻¹) with 120 kg N ha⁻¹. Dashora (1998) observed similar results.

Grain yield of sorghum was found to increase linearly from 26 to 42 q ha⁻¹ with increasing levels of nitrogen from 0 to 150 kg N ha⁻¹, but decreased after that with 200 kg N ha⁻¹ (Singh, *et al.*, 1987). Thus, the response of increasing levels of nitrogen was found curvilinear (Locke and Hons, 1989). Application of 150 kg N ha⁻¹ recorded the highest grain yield of 42 q ha⁻¹ and total biomass of 138.2 q ha⁻¹ at IARI, New Delhi (Saheb *et al.*, 1997). At another locations sorghum has shown response up to 120 kg N ha⁻¹ (Kushwaha and Chandel, 1997 and Barik *et al.*, 1998).

Chudhary and Khade (1991) reported that crop fertilized with 150 kg N ha⁻¹ produced higher yield by 8.1 q ha⁻¹ over 50 kg N ha⁻¹. Dashora *et al.* (1992) recorded 9.8 q ha⁻¹ higher yield with 80 kg N over no nitrogen application. Significant increase in sorghum grain and fodder yield due to application of 80-120 kg N ha⁻¹ were also confirmed by Wanjari *et al.* (1992) and Mahakulkar *et al.* (1992). On N deficient sandy loam soils of Sumerpur (Rajasthan), application of 80 kg N ha⁻¹ enhanced grain yield by 58 and 18 per cent over no N and 40 kg N ha⁻¹ (Singh *et al.*, 1993). Sorghum grown during winters at Navasari (Gujarat) also showed positive response upto 120 kg N ha⁻¹ (Patel *et al.*, 1993).

Under N deficient soils, application of 80 kg N ha⁻¹ produced 34.7 per cent higher yield over control (Dashora and Porwal, 1994). The multi-locational trials conducted under auspicious of AICSIP during *kharif* 1994 revealed that successive increase in N application from 0-40, 40-80 and 80-120 kg ha⁻¹ increased grain yield

by 8.0, 6.96 and 2.87 q ha⁻¹, respectively, while the corresponding increases during 1995 was to the magnitude of 9.31, 5.93 and 2.27 q ha⁻¹. On the basis of experiment it was concluded that for dual purpose varieties, 80 kg N ha⁻¹ was optimum dose whereas 120 kg ha⁻¹ maximized it (NRCS, 1994 and 1995). In sweet sorghum optimum dose of N was worked out to be 80 kg ha⁻¹ (Balasubramanian and Ramamoorthy, 1996). Similarly on clay loam soils, application of 80 kg N ha⁻¹ increased yield by 56 per cent over control .(Kumawat and Bansal, 1996). Studies conducted at Pantnagar (U.P.) revealed that application of 120 kg N ha⁻¹ significantly increased sorghum grain yield (Kushwaha and Chandel, 1997). Dashora (1998) recorded 28 per cent higher grain yield with 120 kg N ha⁻¹ over 40 kg N ha⁻¹.

Patel *et al.* (1990) recorded 25 per cent higher stover yield with 120 kg N ha⁻¹ over control. On N deficient loamy soils of Udaipur (Rajasthan) application of 80 kg N ha⁻¹ increased stover yield by 24.7 q ha⁻¹ over no N (Dashora *et al.*, 1992). At Junagarh (Gujarat) crop fertilized with 120 kg N ha⁻¹ recorded yield of 143 q ha⁻¹ which was higher by 27.20 per cent over control (Hirpara *et al.*, 1992). Mahakulkar *et al.* (1992) recorded highest fodder yield (12.40 t ha⁻¹) with the application of 120 kg N ha⁻¹ over control (19.10 t ha⁻¹). Similarly, at Akola (Maharashtra), application of 80 kg N ha⁻¹ recorded significantly higher stover yield of 126 q ha⁻¹ which was higher by 23.40 per cent over control (Wanjari *et al.*, 1992). Under rainfed conditions of Coimbatore, increasing rates of N from 20 to 40 kg ha⁻¹ increased stover yield marginally by 6 per cent, only (Balasubramanian *et al.* 1993). Whereas in south Rajasthan at Udaipur, Dashora and Porwal (1994) failed to record significant increase in stover yield beyond 80 kg N ha⁻¹ under rainfed conditions. At Jabalpur (M.P.), increasing rates of N from 0-120 kg ha⁻¹ increased stover yield by 123 per cent (Shukla and Sharma, 1994). The results of multilocation experiments during the year 1994 revealed that successive increase in N application from 0-40, 40-80 and 80-120 kg ha⁻¹ increased stover yield by 24.5, 18.4 and 10.8 q ha⁻¹, respectively. While in the year 1995 the corresponding increases were by 25.8, 17.8 and 4.1 q ha⁻¹ (NRCS, 1994 and 1995). At Udaipur, increasing rates of N from 0-80 kg ha⁻¹ increased stover yield by 40 per cent (Kumawat and Bansal, 1996). At Jalalgarh (Bihar), green forage yield of 'MP Chari' showed response upto 100 kg N ha⁻¹ (Vashishatha and Dwivedi, 1997). Dashora (1998) recorded 8.9 and 14.2 per cent higher stover yield with the application of 80 and 120 kg N ha⁻¹ over 40 kg N ha⁻¹, respectively. Crop fertilized with 80 kg

and 120 kg N ha⁻¹ produced the maximum grain yield (18.20 q ha⁻¹) while fodder yield (45.92 q ha⁻¹) was highest with that of 120 kg N ha⁻¹ (Poonia *et al.*, 1999).

An increase in grain, fodder and biological yield with application of 40 kg P₂O₅ ha⁻¹ was also reported by Meghwanshi (1992). The response of sorghum to phosphorus application have been extensively reported and P application is generally recommended. Zade *et al.* (1995) observed that application of 30 kg P₂O₅ ha⁻¹ increased average sorghum yield from 20.05 to 26.68 q ha⁻¹. Further, higher rates did not increase grain yield. At Rahuri, Raskar (1999) found that application of 45 kg P₂O₅ ha⁻¹ recorded significantly higher grain yield of sorghum over 30 and 15 kg P₂O₅ ha⁻¹. The corresponding percent increases were by 4.62 and 18.27, respectively. He further reported that application of P₂O₅ had no effect on dry fodder yield.

Mali *et al.* (2000) working at Udaipur (Rajasthan) studied various cultivars of *Sorghum bicolor* and recorded the highest fodder yield (152.22 q ha⁻¹) with CSV 15 and highest grain yield (42.83 q ha⁻¹) was recorded with CSH 14 when the crop fertilized with 80 kg N + 40 kg P₂O₅ ha⁻¹.

Finding of the experiment conducted by Bishnoi *et al.* (2004) revealed that application of 100 kg N ha⁻¹ recorded significantly higher grain yield, green and dry fodder yields over 80 kg ha⁻¹. The magnitude of increases were by 15.11, 8.30 and 14.86 per cent, respectively. Further, increment in nitrogen level to 120 kg ha⁻¹ found statistically at par with 80 kg N ha⁻¹. At Udaipur (Rajasthan), Kaushik and Shaktawat (2005) reported that application of 80 and 120 kg N ha⁻¹ recorded significantly higher in grain and fodder yield over 40 kg N ha⁻¹ and control. On mean basis the magnitude of increases were by 11.86 & 47.96, 14.68 & 51.69 in grain yield 16.93 & 40.38, 20.42 & 44.57 in fodder yield, respectively. However application of 40 kg N ha⁻¹ recorded significantly higher in harvest index over control.

At Konkan, Khade *et al.* (1989) found progressive increase in grain yield with fertilizer rates of 40 + 20, 80 + 40 and 120 + 60 kg N + P₂O₅ ha⁻¹ on medium black soil. Similarly, Chaudhary and Khade (1991) also observed a progressive increase in grain yield with increasing rates of NPK. Increase in sorghum yield by 15.9 per cent with application of 60 kg N + 60 kg P₂O₅ ha⁻¹ over control (48.8 q ha⁻¹) was recorded by Oleksenko *et al.* (1988). In Gujarat, sorghum genotype GJ-37 produced significantly higher grain yield (41.1 q ha⁻¹) with application of 80 kg N + 40 kg P₂O₅ ha⁻¹ (Patel *et al.*, 1989). An adequate and balanced supply of plant nutrients is essential for obtaining higher yields. While working at Ludhiana, Brar *et al.* (1990) reported

that grain yield of sorghum was enhanced up to 80 kg N and 20 kg P₂O₅ ha⁻¹, however, higher fertility rate did not give further increase in grain yield. According to Kandiannan and Rangaswamy (1990), the contribution of fertilizer was the highest in increasing the sorghum yield. Dakore and Mungikar (1991) noted an increase in dry matter yield with the application of NPK fertilizers. The utilization of fertilizer N and P was 22-36 and 9-24 per cent, respectively. At Jhansi, (Uttar Pradesh) maximum dry matter yield (52.7 q ha⁻¹) was recorded with application of 100 per cent recommended level of N and P i.e. 60 kg N + 40 kg P₂O₅ ha⁻¹ (Niranjan and Arya, 1992). More *et al.* (1994) obtained higher grain yield of sorghum with 50 kg N and 25 kg P₂O₅ ha⁻¹ as compared to 50 kg N ha⁻¹ alone.

A linear increase in grain yield of sorghum hybrid CSH-9 was noted with 50, 75 and 100 per cent recommended dose of fertilizers i.e. 120 kg N + 60 kg P₂O₅ + 60 kg K₂O ha⁻¹ (Kasole *et al.*, 1994). Raghuwanshi and Umat (1994) observed that fertility level of 120 kg + 60 kg P₂O₅ + 40 kg K₂O ha⁻¹ gave maximum grain yield (42.97 q ha⁻¹) a, compared to control (14.81 q ha⁻¹). The studies of Jadhav (1994) at Pune (Maharashtra) revealed that grain and fodder yield of sorghum decreased, by 16.74 and 12.03 per cent, respectively when fertility level was reduced to half.

Application of 100 kg N + 60 kg P₂O₅ + 40 kg K₂O ha⁻¹ produced significantly higher grain yield (21.3 q ha⁻¹) of sorghum over 50 kg N + 30 kg P₂O₅ + 20 kg K₂O ha⁻¹ (15.85 q ha⁻¹) (Raghuwanshi *et al.*, 1990). Tomar and Raghu (1993) also observed similar results. At Pantnagar, application of 100 kg N + 50 kg P₂O₅ ha⁻¹ produced significantly higher grain and stover yields of sorghum. (Singh *et al.*, 1996 and Pal *et al.*, 1996). Every corresponding rise in fertility levels to 50, 75 and 100 per cent recommended dose to sorghum significantly enhanced the grain production up to the highest level of 100 kg N + 60 kg P₂O₅ + 40 kg K₂O ha⁻¹ (Dubey *et al.*, 1997).

At Akola, Coimbatore, Dharwad, Indore, Palem, Pantnagar, Parbhani, Surat and Udaipur experiments conducted during 1997-98 to evaluate the performace of sorghum genotypes at six fertility levels (0 : 10, 20 : 10, 40 : 20, 60 : 30, 80 : 40, 100 : 50 kg N : P₂O₅ ha⁻¹, respectively). Pooled results revealed that application of 100 : 50 kg N : P₂O₅ ha⁻¹ recorded significantly higher grain and fodder yield over rest of the levels and recorded 6.80, 15.56, 24.90, 51.19 and 95.11 per cent increase in grain and 4.86, 9.74, 17.46, 21.34 and 54.83 per cent increase in fodder yield, respectively over 80 : 40, 60 : 30, 40 : 20, 20 : 10 and 0 : 0 kg N : P₂O₅ ha⁻¹ (NRCS, 1997-98).

While studying the effect of continuous use of balanced fertilization, Bhatia and Sikarwar (1995) found a decreasing trend for sorghum-wheat production with the application of nitrogen alone indicating a need of P application in addition to nitrogen for sustaining crop production. They concluded that continuous application of 120 kg N + 80 kg P₂O₅ + 40 kg K₂O ha⁻¹ could sustain the yield without serious depletion in soil fertility.

Evaluation of sorghum genotypes for their response to different fertility levels multilocation field experiments conducted during *kharif* 1995 at Parbhani, Akola, Dharwad, Palem, Indore, Coimbatore, Surat, Pantnagar and Udaipur revealed that application of 80 : 40 kg N : P₂O₅ ha⁻¹ recorded mean grain (43.58 q ha⁻¹) and fodder (98.04 q ha⁻¹) yield which was significantly higher over rest of the fertility levels except beyond this fertility level (100 : 50 kg N : P₂O₅ ha⁻¹) grain and fodder yields were found at par (NRCS, 1995).

Balasubramanian and Ramamoorthy (1996) concluded that 120 kg N + 60 kg P₂O₅ ha⁻¹ was the optimum dose for getting higher yields of sorghum. Mahakulkar *et al.* (1998) also concluded that recommended dose of fertilizer (80 kg N + 40 kg P₂O₅ ha⁻¹) proved productive and profitable than the other nutrient treatments tried in sorghum based cropping system at Akola. Findings of field experiment conducted at Udaipur (Rajasthan) by Khatik *et al.* (1999) revealed that application of 100 % recommended dose of fertilizers i.e. 80 kg N + 40 kg P₂O₅ ha⁻¹ produced significantly higher grain and fodder yield over 60 : 30, 40 : 20 and 20 : 10 kg N P₂O₅ ha⁻¹. The corresponding increases were by 16.76, 33.97 & 151.81 and 24.93, 39.40 & 90.13 per cent, respectively in grain and fodder yield. However, higher to this level was found at par to 80 kg N + 40 kg P₂O₅ ha⁻¹.

At Kolhapur (Maharashtra), the response fertilizer ratio was maximum (7.29) at recommended level of NPK (120 kg N + 60 kg P₂O₅ + 60 kg K₂O ha⁻¹) under irrigated conditions. The same ratio was obtained at 50 per cent of this recommended dose under rainfed conditions (Sharma *et al.*, 1999). Mali *et al.* (2000) at Udaipur, revealed that application of 80 + 40 kg N : P₂O₅ ha⁻¹ recorded significantly higher grain and fodder yield over 50 percent RDF (40 : 20 kg N : P₂O₅ ha⁻¹) amounting to per cent increases of 14.71 and 10.14, respectively. While, Dashora *et al.* (2004) at Udaipur showed that application of 80 kg N + 40 kg P₂O₅ ha⁻¹ recorded significantly 16.78, 37.15, 65.64 and 16.50, 28.29 and 43.41 per cent higher grain and fodder yield over 60 : 30, 40 : 20 and 20 : 10 kg N : P₂O₅ ha⁻¹ respectively.

Patidar and Mali (2004) at Udaipur, studied that application of 75 percent RDF (60 kg N + 30 kg P₂O₅ ha⁻¹) recorded significantly higher grain and fodder yield over 50 per cent (40 kg N + 20 kg P₂O₅ ha⁻¹) and control. The magnitude of increases were by 11.93 & 32.49 and 10.32 & 27.63 per cent, respectively.

Singh *et al.* (2004) at Udaipur revealed that application of 80 kg N : 40 kg P₂O₅ ha⁻¹ recorded significantly higher in grain, fodder and biological yields over 40 : 20 kg N P₂O₅, 10 t FYM and control. However, 50 per cent RDF (40 : 20 kg NP ha⁻¹) also found significantly superior over control. Chotiya (2005) reported that increasing nitrogen application from 0 to 40, 80 and 120 kg ha⁻¹ gave increases in green fodder yield by 22.08, 43.40 and 49.60 per cent and dry fodder by 23.50 44.89 and 48.04 per cent, respectively over control. Successive increase in phosphorus level from 0 to 20, 40 and 60 kg ha⁻¹ gave increases in green and dry fodder yield by 16.83, 31.74, 33.97, 18.45, 33.27, 34.58 per cent, respectively. The fodder yield at 80 kg N + 40 kg P₂O₅ ha⁻¹ was found to be the optimal fertilizer dose. Dixit *et al.* (2005) at Pantnagar showed that application of 80 : 40 kg N : P₂O₅ ha⁻¹ recorded significantly higher grain and fodder yields and registered 14.24 and 9.42 per cent, higher over 40 : 20 kg N : P₂O₅ ha⁻¹, respectively. Findings of Sumeriya *et al.* (2005) at Udaipur revealed that application of 80 : 40 kg N : P₂O₅ ha⁻¹ recorded higher fodder yield over 40 : 20 and 0 : 0 kg N : P₂O₅ ha⁻¹.

Kushwaha and Thakur (2006) at Indore revealed that application of 80 kg N + 40 kg P₂O₅ ha⁻¹ recorded significantly higher in grain and fodder yield, gross and net returns and B:C ratio over 40 kg N + 20 kg P₂O₅ ha⁻¹ and control. Singh and Sumeriya (2006) reported that application of 80 kg N + 40 kg P₂O₅ ha⁻¹ recorded significantly higher grain and fodder yield over 40 kg N + 20 kg P₂O₅ and control.

2.3.7 Harvest index

A significant improvement in harvest index of sorghum with application of nitrogen up to 80 kg N ha⁻¹ was reported by Meghwanshi (1992). The application of 80 kg N ha⁻¹ significantly increased the harvest index (27.8 percent) over 40 kg N ha⁻¹ (27.0 per cent) and control (25.8 per cent), respectively (Kumawat and Bansal, 1996). Poonia (1997) reported that harvest index was increased significantly with the application up to 80 kg N ha⁻¹ (32.4 per cent) and decreased with further increase in the N rate up to 120 kg N ha⁻¹ (26.05 per cent). Sharma (1997) also reported similar results. Sharma and Jain (1997) observed that application of 90 kg N ha⁻¹ increased

harvest index of sorghum (28.43 per cent) over 30 kg N ha⁻¹ (27.27 per cent). Application of nitrogen up to 120 kg N ha⁻¹ significantly increased harvest index of dual purpose sorghum during 1994, whereas, the influence of nitrogen application on harvest index was not significant during 1995 (Dashora, 1998).

Meghwanshi (1992) observed that a successive increase in phosphorus application up to 40 kg P₂O₅ ha⁻¹ significantly increased harvest index of sorghum. The harvest index of sorghum genotype CSH 6 increased with full dose of fertilizer (75 kg N + 50 kg P₂O₅ ha⁻¹) as compared to half dose (Jadhav, 1994). However, Singh *et al.* (1996) noted that the harvest index did not differ significantly amongst fertility levels, as the grain yield did not increase proportionately to stover yield with increase in NP fertilization. Similar findings was also reported by Patidar (1999) at Udaipur (Rajasthan).

At Udaipur (Rajasthan), Kaushik (2000) reported significant improvement in harvest index of sorghum var. CSV 10 with application of nitrogen up to 40 kg N ha⁻¹. The margin of increase over control was 7.43 per cent. Whereas higher to this level i.e. 80 and 120 kg N ha⁻¹ found statistically at par to 40 kg N ha⁻¹. At Udaipur, Singh *et al.* (2004) recorded significantly higher harvest index of sorghum genotypes at 100 per cent (80 kg N + 40 kg P₂O₅ ha⁻¹) and 50 percent RDF (40 kg N + 20 kg P₂O₅ ha⁻¹) over control. The corresponding increases was 8.41 and 9.45 per cent, respectively over control. However, 100 percent, 50 percent RDF and 10 t FYM ha⁻¹ were found at par to each other. However, Dixit *et al.* (2005) at Pantnagar revealed that application of 80 kg N + 40 kg P₂O₅ ha⁻¹ recorded significantly higher harvest index over 40:20 kg N:P₂O₅ ha⁻¹ by a margin of 2.92 per cent.

2.3.8 Content and uptake of nutrients

The higher uptake of N, P and K was noticed at Coimbtore (Jayakumar *et al.*, 1987) Hyderabad (Raja and Reddy, 1987) and Jaipur (Kumar, 1993). The application of 120 kg N ha⁻¹ resulted in maximum uptake of N and P (180.12 kg N and 60.01 kg P ha⁻¹) as compared to 40 kg N ha⁻¹ (143.34 kg N and 51.34 kg P ha⁻¹) (Dashora, 1998). Application of nitrogen improved N content in grain and stover of sorghum Patel, 1993).

Tsai *et al.* (1990) found that application of phosphorus significantly increased P content in plant tissue at 30 DAS. Das *et al.* (1996) noted an increase in the P concentration with application of P₂O₅ up to 60 kg ha⁻¹ in soil containing Olsen's P up

to 10.5 ppm. With higher soil test values (15.4 and 17.6 ppm), the response was observed only up to 40 kg P ha⁻¹ application. They further reported that P concentration at boot leaf stage was higher than at 50 per cent flowering and at maturity.

Increase in uptake of N, P and K with application of fertilizer was reported by Duraisamy (1990). On an average, every 100 kg of sorghum grain required 2.07 kg N, 0.34 kg P and 2.04 kg K (Sonar *et al.*, 1990). The importance of balanced nutrition was reflected in higher yield and a greater diversion of the absorbed nutrients towards the grain (Guldekar *et al.*, 1992). They reported that recoveries of N and P in the heads of sorghum were lower unless both the nutrients were applied. As N and P are intimately related, the utilization of added P increased markedly with N application and N uptake with P application (Shinde *et al.*, 1993). However, the use efficiency decreased with increase in application of these nutrients. Pal *et al.* (1996) found that NPK content and uptake were higher with application of 100 kg N + 50 kg P₂O₅ ha⁻¹ as compared to 20 kg N + 10 kg P₂O₅ ha⁻¹. Respective increases in NPK uptake were 60, 61 and 39.2 per cent. Similarly, Balasubramanian and Ramamoorthy (1996) and Patil and Varade (1998) also reported increase in NPK uptake with increasing levels of fertilizers.

Marked improvement in the N content with increase in N level was reported by Kobale *et al.* (1990). However, they recorded marginal improvement in P and K content due to nitrogen application. An increase in N and P content of grain with application of nitrogen fertilizer to sorghum was observed (Kumar, 1993; Poonia, 1997 and Dashora, 1998). Panwar *et al.* (1988) concluded that increasing rates of P₂O₅ increased content and uptake of N, P and K by sorghum. However, Meghwanshi (1992) reported that phosphorus application improved concentration and uptake of both N and P in grain and stover. Patel *et al.* (1993) reported that phosphorus application did not have much influence on N content and uptake in sorghum. Similar results were also reported by Shinde *et al.* (1993). Sahrawat *et al.* (1998) found that the uptake of macro and micro nutrient elements increased with increase in P application registering maximum uptake at 40 kg P₂O₅ ha⁻¹. Phosphorus application also increased nutrient harvest index for macro and micronutrients.

In a field trials conducted at Akola, Maharashtra (1988-93), sorghum cv CSH 9 was grown in *kharif* and given 11 different fertilizer treatments including NPK fertilizers, FYM and ZnSO₄. The uptake of N, P and K in crop was highest with 100

kg N + 50 kg P + 40 kg K₂O ha⁻¹ + 10 + FYM ha⁻¹ (Naphade *et al.*, 1995). Khatik *et al.* (1999) at Udaipur, recorded that application of 80 kg N + 40 kg P₂O₅ ha⁻¹ obtained significantly higher N, P and K uptake over 60:30, 40:20 and 20:10 kg N:P₂O₅ ha⁻¹ to the magnitude of 32.02, 59.00 and 142.96 per cent in nitrogen; 22.63, 44.41 and 111.06 per cent in phosphorus and 25.30, 36.54 and 100.82 per cent in potassium.

At Udaipur, Patidar (1999) revealed that application of 80 kg N + 40 kg P₂O₅ ha⁻¹ recorded significantly higher N, P and K content and uptake by grain, fodder and total uptake by crop over 60:30, 40:20 kg N : P₂O₅ ha⁻¹ and control. Findings of a field experiment conducted at Arnej (Gujarat), wherein hybrid fodder sorghum cv GFSH 1 fertilized with 0-60 kg N ha⁻¹ and 0-20 kg P₂O₅ ha⁻¹. Results revealed that N and P content and uptake increased with increase in NP application rate (Das *et al.*, 2000). At Bhavanisagar, application of 120 kg N ha⁻¹ significantly increased nutrient uptake by sweet sorghum (Balasupramanian and Ramamoorthy, 1996). In Tamil Nadu, application of 120 kg N ha⁻¹ improved the N uptake by sorghum (Duraiswami *et al.*, 2001).

Bishnoi *et al.* (2003) at Udaipur (Rajasthan) revealed that application of 80 kg N ha⁻¹ significantly increased N content in grain and fodder and its uptake by grain, fodder and total uptake over 40 kg N ha⁻¹. The corresponding increases with 80 kg N ha⁻¹ over 40 kg N ha⁻¹ were by 20.97, 22.27 and 21.55 per cent, respectively. However, higher to this level (i.e. 120 kg N ha⁻¹) failed to bring about significant improvement in nitrogen uptake. Similarly, Kaushik and Shaktawat (2005) reported that application of 80 kg N ha⁻¹ recorded significantly higher N and P uptake by grain, fodder and total uptake over 40 kg N ha⁻¹ and control.

In an other experiment at Udaipur, Jat *et al.* (2003) revealed that application of 80 kg N + 40 kg P₂O₅ ha⁻¹ recorded significantly higher N, P, K, Zn, Fe, Mn and Cu content in grain and stover and their uptake over lower doses of fertilizers. Chotiya (2005) at Udaipur concluded that application of 80 kg N ha⁻¹ recorded highest N and P content and uptake over lower levels of nitrogen. Application of 40 kg P₂O₅ ha⁻¹ reported highest N and P content and their uptake compared with their lower levels. Dixit *et al.* (2005) at Pantnagar, reported that application of 80 kg N + 40 kg P₂O₅ ha⁻¹ (100 percent RDF) recorded significantly higher N, P and K uptake over 40 kg N + 20 kg P₂O₅ ha⁻¹ and the per cent increases by a margin of 13.80, 16.89 and 15.31, respectively.

Findings of an experiment conducted by Sumeriya *et al.* (2005) at Udaipur revealed that application of 80 kg N + 40 kg P₂O₅ ha⁻¹ recorded significantly higher content and uptake of nitrogen over 40 kg N + 20 kg P₂O₅ ha⁻¹ and control. The magnitude of increases were by 12.68 and 37.52; 14.85 and 51.27; 14.14 and 46.53 per cent in grain, fodder and total uptake by crop over 40 kg N + 20 kg P₂O₅ ha⁻¹ and control, respectively. Further results also revealed 40 kg N + 20 kg P₂O₅ ha⁻¹ that recorded 22.04, 31.71 and 28.38 per cent higher nitrogen uptake by grain, fodder and total uptake by the crop over unfertilized control.

2.3.9 Protein content

Application of nitrogen up to 150 kg N ha⁻¹ increased protein content in sorghum grain (Thakre *et al.*, 1989). The crude protein content and protein yield also showed improvement up to application of 120 kg N ha⁻¹ (Malik *et al.*, 1992). The grain protein contents increased with increasing N and P levels (Shinde *et al.*, 1993).

Application of 60 kg N + 30 kg P₂O₅ ha⁻¹ yielded significantly higher protein content in grain than 30 kg N + 15 kg P₂O₅ ha⁻¹ and control (Gangwar and Singh, 1992). Similarly, Jadhav (1994) also reported that protein content and protein production increased with full dose of fertilizers (75 kg N + 50 kg P₂O₅ ha⁻¹) as compared to half dose. Pal *et al.* (1996) found that protein content was higher by 57.6 per cent with application of 100 kg N + 50 kg P₂O₅ ha⁻¹ as compared to 20 kg N + 10 kg P₂O₅ ha⁻¹.

Significant improvement in protein content and production with 75 kg N ha⁻¹ was also noticed by Jadhav (1994). Significant improvement in protein content in grain and fodder with 80 kg N ha⁻¹ was also reported by Poonia (1997) at Udaipur (Rajasthan). Sorghum fertilized with 150 kg N ha⁻¹ recorded significantly higher protein yield by sorghum grain (Kushwaha and Chandel, 1997). Dashora (1998) observed that N fertilization not affected protein content in grain significantly but it had a significant effect on protein content in stover of dual purpose cultivar CSV-15.

Reduction in grain protein content was observed by Dashora (1998) with the increasing nitrogen levels whereas stover protein content significantly increased by 11.2 per cent with 120 kg N over 40 kg N ha⁻¹ in dual purpose sorghum variety CSV-15.

Kaushik (2000) at Udaipur, revealed that application of 120 kg N ha⁻¹ recorded significantly higher crude protein content in grain over 80, 40 and 0 kg N

ha⁻¹ and registering 3.97, 9.63 and 30.11 per cent, respectively. Bishnoi (2002) at Udaipur, revealed that application of 120 kg N ha⁻¹ registered significantly higher protein content over 100 and 80 kg N ha⁻¹. The corresponding increases were by 5.16 and 21.96 per cent. Jat *et al.* (2003) at Udaipur, recorded that protein content increased with full dose of fertilizers (80 kg N + 40 kg P₂O₅ ha⁻¹) as compared to 50 percent RDF (40 kg N + 20 kg P₂O₅ ha⁻¹) and control. The corresponding increases were by 6.53 and 31.47, respectively.

Findings of a field experiment conducted at Udaipur by Patidar and Mali (2004) revealed that application of 100 percent RDF (80 kg N + 40 kg P₂O₅ ha⁻¹) recorded significantly higher in protein content in grain over 60:30, 40:20 kg N : P₂O₅ ha⁻¹ and control. The magnitude of increases were by 2.75, 5.66 and 13.13 per cent, respectively. Similarly, Sumeriya *et al.* (2005) at Udaipur noted that application of 100 percent RDF (80 kg N + 40 kg P₂O₅ ha⁻¹) increased protein content in grain by 10.12 and 30.97 per cent high over 50 percent RDF (40 kg N + 20 kg P₂O₅ ha⁻¹) and control.

3. MATERIALS AND METHODS

A field experiment entitled “Effect of plant geometry and fertility levels on productivity of various elite sorghum [*Sorghum bicolor* (L.) Moench] genotypes” was conducted during *kharif* seasons 2003 and 2004. The details of experimental techniques followed and criteria adopted for evaluation of treatments are presented in this chapter.

3.1 EXPERIMENTAL SITE

The experiment conducted during both the years were laid out at Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, Udaipur. The site was situated at 24°.35'N latitude, 74°.42'E longitude and an altitude of 579.80 m above sea level. The region falls under agro-climatic zone IV-A (Sub-Humid Southern Plain and Aravalli Hills) of Rajasthan.

3.1.1 Climate and weather conditions

This zone possess a typical sub-tropical climatic conditions characterized by mild winters and moderate summers associated with high relative humidity during the months of July to September. The mean annual rainfall of the region is 637 mm, most of which is contributed by South-west monsoon from July to September. In summers, maximum temperature goes upto 46°C in May and June are the hottest months. Winters are generally rainless and minimum temperature during December and January falls as low as 1°C.

The mean weakly meteorological observations recorded at Agromet observatory, Rajasthan College of Agriculture, Udaipur during cropping periods are presented in Appendix I and depicted in Fig. 3.1. A perusal of data revealed that the maximum and minimum temperatures during the crop growth period ranges between 28.2 to 33.3 and to 12.7 to 25.4 °C, respectively during the year 2003. The corresponding fluctuations during second year of experiment were 28.6 to 34.0 and 12.7 to 25.2 °C. The total rainfall received during the crop season of the year 2003 was 465.9 mm and 569.6 mm in 2004, respectively. The evaporation from the USWB Class-A pan evaporimeter during the corresponding crop seasons ranged from 0.9 to 9.7 and 3.1 to 7.5 mm per day, respectively.

3.2 PHYSICO-CHEMICAL PROPERTIES OF THE SOIL OF THE EXPERIMENTAL FIELD

To evaluate physico-chemical properties of soil samples were drawn randomly from different spots of the experimental field, from 0-15 cm depth before layout of the experiment. The samples were thoroughly mixed, dried, sieved and thus, a composite sample was prepared for subsequent physico-chemical analysis in the laboratory. The values of soil analysis along with methods followed are presented in Table 3.1.

It is evident from the Table 3.1 that the soils of the experimental field was clay loam in texture and alkaline (pH 8.00 and 8.10) in reaction. The soil was found to be medium with respect to available nitrogen (286.50 and 290.75 kg ha⁻¹) and phosphorus (19.50 and 19.95 kg ha⁻¹) and high in available potassium (389.00 and 392.00 kg ha⁻¹). The soil contains high amount of calcium carbonate content (3.68 and 3.72 per cent).

3.3 CROPPING HISTORY OF THE EXPERIMENTAL FIELD

Wheat as a commercial crop was a taken in previous years to homogenized the fertility of field after that during *kharif* 2003 and *kharif* 2004, these experiments were undertaken.

Year	Experimental crop	Rabi
2002-03	Maize	Wheat
2003-04	Sorghum	Wheat
2004-05	Sorghum	Wheat

3.4 DETAILS OF TREATMENT AND EXPERIMENTAL DESIGN

The experimental treatments consisted of 3 genotypes, 3 plant geometry and 4 levels of fertility. Thus, making 36 treatment combinations were replicated thrice in split plot design. Treatment details are given in Table 3.2. The layout of plan alongwith the treatment allocation is depicted in Fig. 3.2.

Table 3.2. Details of the treatments and symbols used

	Treatments	Symbol
(A)	Genotypes	
	CSV 15	G ₁
	SPV 1430 (Pratap Jowar 1430)	G ₂
	CSH 14	G ₃
(B)	Plant geometry /densities	
	45 x 15 cm - 1.50 lac plants ha ⁻¹ or normal density	P ₁
	45 x 10 cm - 2.20 lac plants ha ⁻¹ or medium density	P ₂
	30 x 10 cm - 3.30 lac plants ha ⁻¹ or high density	P ₃
(C)	Fertility levels (%)	
	50% RDF or 40 kg N + 20 kg P ₂ O ₅ ha ⁻¹	F ₁
	75% RDF or 60 kg N + 30 kg P ₂ O ₅ ha ⁻¹	F ₂
	100% RDF or 80 kg N + 40 kg P ₂ O ₅ ha ⁻¹	F ₃
	(recommended dose of fertilizers)	
	125% RDF or 100 kg N + 50 kg P ₂ O ₅ ha ⁻¹	F ₄

3.4.1 Other experimental details

- (a) Crop : Sorghum
- (b) Genotype : CSV 15, SPV 1430 and CSH 14
- (c) Design : Split plot design
- (i) Main plot treatment : Genotypes and plant geometry/ density
- (ii) Sub plot treatment : Fertility levels
- (d) Total treatment combinations : 36
- (e) No. of replications : 3
- (f) Total number of plots : 108
- (g) Plot size (i) Gross : 4.50 x 5.00 m
- (ii) Net : 3.60 x 4.00 m

3.4.2 Treatment application

- a) **Genotypes** : Sorghum genotypes i.e. CSV 15, SPV 1430 and CSH 14 were sown as per plan of layout. Objective of selection of varieties and hybrid as all the genotypes i.e. varieties and hybrid were chosen for present investigation

because of the fact that all of them are included in package and practices for Rajasthan. Hence to find out the comparative performance under different treatments i.e. plant geometry and fertility levels these genotypes were selected. So that proper recommendation can be given to the farmers with respect to genotypes.

- (i) **CSV 15** : Developed by NRCS, Hyderabad. Pedigree of the variety is SPV 475 x SPV 462, released in the year 1996 and recommended for dual purpose for all sorghum growing areas of the nation. Variety is tall (230-240 cm) with days to flowering (62-67 days) and maturity (95-110 days). It has grain yield potential of about 35-40 q ha⁻¹ and dry fodder yield potential of 120-125 q ha⁻¹.
- (ii) **SPV 1430 (Pratap Jawar 1430)** : Developed by AICSIP, Udaipur centre and released in 2003 from selection of genotype SPV 96. This variety is suitable for normal to low rainfall areas of this state. It flowers in 55-60 days and matures in 90-95 days with plant height of 180-200 cm. The grain and fodder yield potential of 35-40 q ha⁻¹ and 110-115 q ha⁻¹, respectively.
- (iii) **CSH 14** : This hybrid developed by AICSIP, Akola centre during 1992 having parentage of AKMS 14 A x AKR 150 and suitable for low rainfall areas of the nation. It takes 55-60 days for flowering and 90-95 days for maturity. The hybrid possess plant height of 170-190 cm with grain yield potential of 35-40 q ha⁻¹ and fodder yield potential of 85-90 q ha⁻¹, respectively.
- b) **Plant geometry** : Sorghum crop was sown at three different plant geometries i.e. 45 x 15, 45 x 10 and 30 x 10 cm by keeping plant population of 1.48, 2.20 and 3.30 lac ha⁻¹.
- c) **Fertility levels** : Fertilizer application was also made as per the treatment. Full dose of phosphorus and half dose of nitrogen was applied at sowing through DAP and urea. The quantity of nitrogen supplied through DAP was adjusted with urea. The remaining dose of nitrogen was top dressed at 30 DAS during first year and 34 DAS during second year of experiment depending upon the occurrence of rains.

3.5 DETAILS OF CROP RAISING

3.5.1 Field preparation

The experimental field was prepared by ploughing once with tractor drawn disc plough followed by cultivator and planking during both the years of

experimentation. The plots were demarketed as per layout plan (Fig. 3.2) and the bunds were prepared to separate out each experimental unit.

3.5.2 Seed and sowing

Sorghum genotypes CSV 15, SPV 1430 and CSH 14 were used as per treatment. The seeds were sown manually as per treatment of plant geometry used in all plots.

3.5.3 Weed control and inter cultivation

A pre-emergence herbicide i.e. atrazine at 0.5 kg per hectare was sprayed for controlling all types weeds in initial stage of crop growth. Thinning was done at 25 DAS to maintain desired plant population in all plots in uniform distance. Hoeing was done at 30 DAS with the help of *kudali* (manually) to maintain proper aeration and soil moisture conservation.

3.5.4 Plant protection

Carbofuran 3G granules were applied at 15 kg ha⁻¹ in furrows at sowing to minimize the infestation of shoot fly. To protect the crop from stem borer carbofuran granules were placed in leaf whorls at 35 DAS. One prophylactic spray of endosulphan 35 EC (0.03%) was also done at 40 days after sowing to control the shoot fly, stem borer and other harmful insects in standing crop. The crop remained disease free during the two seasons of experimentation.

3.5.5 Bird scaring

Effective watching was done to protect the losses due to bird's damage through regular vigilance.

3.5.6 Harvesting and threshing

Plants were harvested from individual net plot with sickle. One border row and one sampling row from either sides of each plot and ½ - ½ metre both the sides in length wise before harvesting of net plot were removed and bulked together and record the yield as for commercial crop. The remaining harvested plants in 4.0 x 2.7 square meter net plots were allowed for sun drying. After complete drying, total weight was recorded for biological yield from each net plot. Then earheads were

harvested from individual net plot with sickle and then threshed. Subtract the grain yield from biological yield to work out the fodder yield per net plot. Weighing of grain was done after winnowing and cleaning. Composite samples of grains (about 100 g) were taken for laboratory studies.

The details of cultural operations along with the dates followed during the two years of experimentation are presented in Table 3.3.

3.6 TREATMENT EVALUATION

Following criteria and methods were adopted for evaluating the effect of the experimental treatments.

(a) Morphophysiological parameters

- 1. Plant population :** Number of plants in each net plot were counted at 20 DAS and at harvest. The population was expressed on hectare basis ($\times 1000 \text{ ha}^{-1}$).
- 2. Plant height :** The height of five randomly selected plants from each plot were measured from ground to tip of the main shoot at 30, 60 and 90 DAS and at harvest. The mean plant height for each treatment was worked out and expressed in cm.
- 3. Dry matter production :** Dry matter production was studied at 30, 60 and 90 DAS and at harvest. Five plants were randomly selected from sampling rows. These plants were first sun dried and then oven dried at 70°C till a constant weight was observed. The dry matter was expressed in g plant^{-1} .
- 4. Days to 50 per cent flowering :** Days to 50% flowering was recorded visually on total plant basis.

(b) Yield and its components

- 1. Weight of earhead :** Five representative ear heads were taken from each plot and weighed after sun drying. The average weight in g per earhead was recorded.
- 2. Length of earhead :** Length of five heads was measured and average value was worked out.
- 3. Number of grains per earhead :** The randomly selected five earheads were used for counting the number of grains with the help of wooden seed counting device. Their average was taken as the number of grains per earhead.

4. **1000 grain weight** : Weight of 1000 grains from bulk yield of each plot was recorded in g.
5. **Grain weight per earhead** : Five earheads from each plot were threshed and cleaned and weight of grain was recorded in grams. Then average grain weight per head was recorded.
6. **Grain yield** : Grain yield of each net plot was recorded separately and finally calculated in terms of quintal per hectare.
7. **Fodder yield** : Subtract the yield of grain from total biological yield recorded in each net plot and calculated and expressed in terms of quintal per hectare.
8. **Biological yield** : After through sun drying of the harvested bundles of each net plot were collected and then their weight was taken for biological yield and then calculated in terms of quintal per hectare.
9. **Harvest index** : Harvest index was calculated by using the formula given by Donald and Hamblin (1976).

$$\text{Harvest index (HI)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

(c) **Biochemical parameters**

1. **Nutrient content** : Representative samples of sorghum (five random plant sample) were taken for dry matter and collect at harvest. After removing earhead plants used for fodder chemical analysis. Grain sample taken from bulk of each plot at the time of winnowing were used for chemical analysis. Grain and fodder samples were grounded separately in grinder made of stainless steel (a wiley mill) having 60 mesh size sieve and used for nutrient content determination as follows :
 - (i) **Nitrogen** : Nessler's reagent method (Lindner, 1944).
 - (ii) **Phosphorus** : Ammonium Vanadate Molybdate yellow colour method (Richards, 1968).
2. **Nutrient uptake** : Nutrient content estimated in grain and stover were used to compute N and P uptake by the crop as under.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content in grain / fodder} \times \text{Grain / fodder yield (kg ha}^{-1}\text{)}}{100}$$

Total nutrient uptake by the crop was computed by summing up the uptake by both grain and fodder.

- 3. Protein content in grain :** The protein per cent in grain was calculated by multiplying nitrogen per cent in grain with factor 6.25 (AOAC, 1960).

3.7 SOIL ANALYSIS

The soil samples were taken upto the depth of 0-15 cm from each plot after harvest of sorghum crop for determination of nitrogen, phosphorus and potassium in soil. The available N was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956). Phosphorus was determined by Olsen's method (Olsen's *et al.*, 1954). Potassium was determined by flame photometer method (Jackson, 1967).

3.8 ECONOMICS OF THE TREATMENTS

In order to evaluate the economic viability of different treatments and to ascertain the most remunerative treatment, economics of different treatment combinations were worked out in terms of net returns ha⁻¹ and B:C ratio. The expenses incurred on cultivation operations from preparatory tillage to harvesting and threshing including cost of input *viz.*, seed, fertilizer, plant protection chemicals applied to each treatment were computed and cost of cultivation was thus worked out. The gross income was worked out on the basis of mean grain and fodder yield per hectare of each treatment and at prevailing market prices during the years 2003 and 2004. The net income per hectare basis was calculated by deducting cost of cultivation from the income per hectare for respective treatments. Benefit : cost ratio was also worked out treatment wise by the following formula :

$$\text{Benefit : Cost ratio} = \frac{\text{Net returns (Rs ha}^{-1}\text{)}}{\text{Cost of cultivation + cost of treatment}}$$

3.9 STATISTICAL ANALYSIS

The standard procedure as suggested by Fisher (1950) were employed by applying the techniques of analysis of variance for “Split Plot Design” in order to test the significance of the experimental results. Wherever ‘F’ test was found significant at 5 per cent level of significance. Critical differences (CD) for the treatment means were worked out. Pooled analysis of the data of sorghum carried out by the standard procedure as described by Gomez and Gomez (1984) to establish the trend of treatment applied. To elucidate effects, summary tables alongwith the SEM \pm and CD were prepared and are given in chapter “experimental results” and their analysis of variance (ANOVA) are given in the appendices II to XXV at the end. Further, the correlation coefficient and regression equations were worked out as described by Panse and Sukhatma (1995).

Table 3.1. Mechanical, physical and chemical properties of the experimental soil

Properties	2003	2004	Method employed
(A) Mechanical composition			
Sand (%)	38.30	39.50	Hydrometer method
Silt (%)	26.75	26.30	(Bouyouces, 1962)
Clay (%)	33.95	32.90	
Texture class	Clay loam	Clay loam	Triangular diagram (Brady, 1983)
(B) Physical composition			
Bulk density (g cc ⁻¹)	1.46	1.48	Core sampler method (Piper, 1950)
Particle density (g cc ⁻¹)	2.65	2.68	Black (1965)
Porosity (%)	45.65	46.17	Black (1965)
(C) Chemical composition			
Organic carbon (%)	0.72	0.75	Rapid titration method (Walkley and Black, 1947)
Organic matter (%)	1.24	1.29	By factor (1.724)
Total nitrogen (kg ha ⁻¹)	286.50	290.75	Modified Kjeldahl's (Jackson, 1967)
Available phosphorus (P ₂ O ₅) (kg ha ⁻¹)	19.50	19.95	Olsen's method (Olsen <i>et al.</i> , 1954)
Available potassium (K ₂ O) (kg ha ⁻¹)	389.00	392.00	Flame photometer (Jackson, 1967)
Calcium carbonate content (%)	3.68	3.72	Ammonium acetate method (Piper, 1966)
Electrical conductivity (dSm ⁻¹ at 25°C)	0.80	0.84	Using solubridge (ed. Richards, 1968)
pH (1:2.5::Soil:Water ratio)	8.00	8.10	Blackman's pH meter Piper, 1950)

Table 3.3. Schedule followed for cultural operations and treatment application in sorghum

S. No.	Operation	Year	
		2003	2004
1.	Field preparation and ploughing	02.07.03	28.06.04
2.	Layout of experiment, individual plot leveling and bunding	09.07.03	02.07.04
3.	Bunding, furrow opening and fertilizer application	11.07.03	03.07.04
4.	Sowing	12.07.03	04.07.04
5.	Fertilizer application		
	(a) Basal	11.07.03	03.07.04
	(b) Top dressing	12.08.03	08.08.04
6.	Herbicide spray	13.07.03	05.07.04
7.	Hoeing and weeding	11.08.03	04.08.04
8.	Plant protection		
	(a) Carbofuran application at sowing	12.07.03	04.07.04
	(b) Carbofuran application in whorls	16.08.03	09.08.04
	(c) Endosulphan	22.08.03	14.08.04
9.	Harvesting	28.10.03	26.10.04
10.	Threshing	08.11.04	04.11.04

4. EXPERIMENTAL RESULTS

The results of the field experiment entitled “Effect of plant geometry and fertility levels on productivity of various elite sorghum [*Sorghum bicolor* (L.) Moench] genotypes” conducted at Instructional Farm, Rajasthan College of Agriculture, Udaipur during the two consecutive years i.e. *kharif* 2003 and 2004, are being presented in this chapter. Data pertaining to the effect of different treatments were statistically analyzed to test of significance of the results. Analysis of variance for these data have been furnished in appendices at the end (II to XXV). The results for main effects and significant interaction effects are being presented in succeeding paragraphs.

4.1 PLANT POPULATION

Genotypes : A perusal of the data set out in Table 4.1 (Appendix II and III) indicate that plant population ha^{-1} recorded at 20 DAS and at harvest were not significantly influenced with genotypes during both the years of experimentation as well as on pooled data of two years basis.

Plant geometry : It is evident from the data given in Table 4.1 that plant geometry (Plant population) had significant effect on plant population at final thinning and at harvest during both the years of experiment. On pooled basis, at final thinning (20 DAS) and at harvest, increases of plant population under plant geometry of 30 x 10 cm were by 46.96 & 112.63 and 49.40 & 120.77 per cent over 45 x 10 and 45 x 15 cm plant geometry, respectively.

Fertility levels : A further reference of the same table reveals that plant population was not affected significantly due to various levels of fertility at final thinning (20 DAS) and at harvest during both the years of experimentation and on pooled data basis.

4.2 GROWTH CHARACTERS

Data on various growth characters of sorghum under the influence of treatments are presented in Table 4.2 to 4.4 and respective analysis of variance have been given in Appendices IV to IX.

4.2.1 Plant height

4.2.1.1 Plant height at 30 DAS

Genotypes : Data presented in Table 4.2 reveals that CSV 15 a dual purpose sorghum genotype registered significantly higher in plant height at 30 DAS over CSH 14 during both the years. However, it was found significantly at par with SPV 1430 at this stage. The tune of increase was of the order of 15.52 per cent over CSH 14 on pooled data basis.

Plant geometry : It is evident from the data presented in Table 4.2 that plant height at 30 DAS did not differ significantly with any of plant geometry during both the years of study.

Fertility levels : It is explicit from data presented in same table reveals that plant height at 30 DAS significantly influenced with the application of 75, 100 and 125 per cent of recommended dose of fertilizers found at par with one another but proved significantly superior over 50 % RDF during both the years of experimentation. On the basis of pooled data increases in plant height at 30 DAS under 75, 100 and 125 % RDF were by 6.06, 7.50 and 8.51 per cent over 50 % RDF, respectively.

4.2.1.2 Plant height at 60 DAS

Genotypes : Data (Table 4.2) shows that plant height at 60 DAS had significant variation due to genotypes. Among genotypes, CSV 15 recorded significantly higher plant height over SPV 1430 and CSH 14. While, both these genotypes i.e. SPV 1430 and CSH 14 were failed to show any significant variation with each other during both the years of experiment. On the basis of pooled data increases were by 7.09 and 10.16 per cent with CSV 15 over SPV 1430 and CSH 14, respectively.

Plant geometry/plant density : It is evident from data given in Table 4.2 that 45 x 15 crop geometry (150,000 plants ha⁻¹) recorded significantly higher plant height over higher plant density i.e. 3.30 lac plants ha⁻¹. However, 2.20 lac plants ha⁻¹ statistically at par with lower and higher plant densities during both the years of experimentation. While, on pooled data basis, both the lower plant densities brought about significantly at par with each other but superior over higher plant density in this respect. The increases with lower and medium densities were to the magnitude of 6.69 and 3.83 per cent over higher plant density (164.67 cm).

Fertility levels : Application of 75-125 % RDF registered significantly higher plant height over 50 % RDF during both the years. While, maximum plant height at 60

DAS was noted with application of 125 % RDF but it was significantly higher over 75% RDF only, 100 % RDF proved statistically at par with 75 and 125 % RDF during both the years of study as well as in pooled data analysis. On the basis of pooled data, 100 % RDF proved their superiority by 18.44 and 2.32 per cent over 50 and 75 % RDF, respectively in plant height at 60 DAS.

Genotypes x fertility levels on plant height at 60 DAS : It is clear from evaluation of data presented in Table 4.2.1 indicate that across the years as well as on pooled basis, all the three test genotypes responded to fertility levels only upto 75% RDF. Further, increase in fertility level upto 125% RDF, none of the genotype brought about significant response in plant height except genotype CSV 15, which was significantly superior at 125% RDF over 75% RDF but failed to show analytical difference over 100% RDF during a couple of years of study and their combined analysis. Data further revealed that, there no significant difference was noted among the genotypes at 50% RDF at 60 DAS stage of the crop growth during both the years of study while, in pooled analysis, CSV 15 gave positive response over CSH 14. Further, increase in fertility CSV 15 obtained significantly higher plant height at same level of fertility over SPV 1430 and CSH 14 during second year of study and pooled analysis but in first year positive response with CSV 15 in plant height at 60 DAS was obtained over genotype CSH 14 only.

4.2.1.3 Plant height at 90 DAS

Genotypes : A reference of the data set out in Table 4.2 indicated that CSV 15 registered significantly superior in plant height at later stage of crop growth i.e. at 90 DAS over SPV 1430 and CSH 14. While, SPV 1430 also found significantly superior over CSH 14 during both the years as well as on pooled data. On pooled data basis increases with CSV 15 were noted with SPV 1430 and CSH 14 by 11.02 and 18.51 per cent, respectively. Genotype SPV 1430 increased the plant height by 6.75 per cent over CSH 14 at 90 DAS stage of crop growth.

Plant geometry : It is explicit from the data presented in Table 4.2 reveals that low plant density (1.50 lac plants ha⁻¹) recorded significantly higher plant height at 90 DAS over remaining densities during the years of experimentation. While, ever increasing in plant densities upto 3.30 lacs ha⁻¹ significantly decreased the plant height at this stage of crop growth. On the basis of pooled data decreases in plant

height were by 4.84 and 12.66 per cent with 2.2 and 3.3 lac plants ha⁻¹, respectively over normal plant density i.e. 1.50 lac plants ha⁻¹.

Fertility levels : A perusal of data presented in Table 4.2 reveals that application of fertility levels from 75-125 % RDF significantly increased the plant height over 50 % RDF at 90 DAS during both the years of experimentation. Application of 100 % RDF recorded significantly higher plant height over 50 % RDF but it was statistically at par with lower and higher levels of fertility. On pooled data basis, 100% RDF gave 13.65 per cent higher plant height over 50 % RDF.

Genotypes x fertility levels on plant height at 90 DAS : A reference to data depicted in Table 4.2.2 reveals that, among the fertility levels application of 75% RDF obtained the significant increase in plant height at 90 DAS with genotypes SPV 1430 and CSV 14 where further increase in fertility levels upto 125% RDF did not able to increase the plant height. While, CSV 15 was positively responded in plant height upto 100% RDF only. Further, genotype CSV 15 was proved their superiority at all the levels of fertility over SPV 1430 and CSV 14 at same level. However, SPV 1430 was also found superior over CSV 14 at same level of fertility upto 125 % RDF in plant height at 90 DAS only on pooled basis.

Table 4.2.2. Interaction effect of genotypes and fertility levels on plant height at 90 DAS (Pooled)

Fertility levels	Genotypes		
	CSV 15	SPV 1430	CSV 14
50% RDF	206.83	193.25	179.38
75% RDF	231.37	212.68	200.74
100% RDF	242.37	214.45	201.75
125% RDF	250.39	218.16	203.71
		SEm±	CD (P=0.05)
Fertility levels at same genotype		3.04	8.51
Genotypes at same or different levels of fertility		4.03	11.29

4.2.1.4 Plant height at harvest

Genotypes : A perusal of data presented in Table 4.2 and their analysis of variances (Appendices IV and V) reveals that genotype CSV 15 registered significantly higher plant height over SPV 1430 and CSH 14 at harvest during both the years of experimentation. On pooled data basis, the tune of increases were of the order of 12.00 and 19.05 per cent, respectively. Further, data reported that genotypes SPV 1430 also proved significantly superior in plant height over CSH 14. The tune of increase was of the order of 6.29 per cent, on pooled basis.

Plant geometry : It is evident from the data (Table 4.2) that plant geometry had significant effect on plant height at harvest during both the years of experiment. But lower and medium densities registered significantly higher plant height over higher plant density (3.30 lac plants ha⁻¹) during both the years, while, both the lower densities (1.50 and 2.20 lac plants ha⁻¹) did not differ significantly in this respect at harvest stage. On pooled data basis increases with 1.50 and 2.20 lac plants ha⁻¹ were 12.18 and 7.62 per cent, respectively over 3.30 lac plants ha⁻¹.

Fertility levels : An examination of data (Table 4.2) reveals that application of 75-125% RDF levels of fertility had significant effect on plant height at harvest over 50 % RDF during both the yeas of experiment. Across the year increment in fertility levels from 50 % RDF to 75 % RDF (60 kg N + 30 kg P₂O₅ ha⁻¹) significantly increased plant height at harvest. Further, increase in fertility levels from 75 to 100 and 100 to 125 % RDF did not bring about significant improvement in plant height. On pooled basis, application of 100 % and 75 % RDF recorded significantly higher plant height at harvest over 50 % RDF by a margin of 13.82 and 10.86 per cent, respectively.

Genotypes x fertility levels on plant height at harvest : A perusal of data (Table 4.2.3) reveals that, under all the fertility levels, application of 75% RDF the significant increased in plant height with all the genotypes at harvest in pooled analysis over 50% RDF except CSV 15 where response of fertility was observed upto 100% RDF and it was significantly higher over 75% RDF. Further increase in fertility level were at par with one an other. Among genotypes, CSV 15 proved significantly superior over SPV 1430 and CSH 14 at same fertility level in pooled analysis in plant height at harvest. While, both genotypes i.e. SPV 1430 and CSH 14 were failed to show any significant variation with same level of fertility except 100% RDF. Where, SPV 1430 was significantly higher over CSH 14 in this respect at harvest.

Table 4.2.3. Interaction effect of genotypes and fertility levels on plant height at harvest (Pooled)

Fertility levels	Genotypes		
	CSV 15	SPV 1430	CSH 14
50% RDF	209.00	193.58	182.37
75% RDF	233.62	213.72	201.16
100% RDF	246.75	216.71	202.32
125% RDF	254.26	218.51	206.81
		SEm±	CD (P=0.05)
Fertility levels at same genotype		3.62	10.16
Genotypes at same or different levels of fertility		4.79	13.43

4.2.2 Dry matter accumulation (DMA)

4.2.2.1 DMA at 30 DAS

Genotypes : An examination of data in Table 4.3 reveals that CSV 15 recorded significantly higher dry matter accumulation over CSH 14 during *kharif* 2003 but in second year CSV 15 was proved significantly superior over both the genotypes i.e. SPV 1430 and CSH 14. Similar results were obtained in combined of two years. Genotype SPV 1430 was reported significantly superior over CSH 14 during both the years. On pooled data basis genotype CSV 15 produced 4.59 and 24.61 per cent higher in dry matte production over SPV 1430 and CSH 14, respectively.

Plant density : A perusal of data presented in Table 4.3 reveals that 1.50 lac plants ha⁻¹ recorded significantly superior in dry matter accumulation over high density level at 30 DAS. While, both lower and medium plant densities did not show any significant variation with each other during both the years of experimentation. On pooled data basis, low and medium plant densities were statistically superior over higher plant density in DMA at 30 DAS stage of crop growth. The increases with 1.50 and 2.20 lac plants ha⁻¹ were by 7.07 and 3.89 per cent, respectively over 3.30 lac plants ha⁻¹ in this respect.

Fertility levels : Application of 50 % RDF registered significantly lower DMA at 30 DAS over rest of the fertility levels during both the years of experimentation.

However, ever increase in fertility levels upto 125 % RDF significantly increased the DMA at 30 DAS during both the years of study. On pooled data basis, 125 % RDF increased DMA by 48.89, 13.18 and 5.35 per cent respectively over 50, 75 and 100 % RDF, respectively.

4.2.2.2 DMA at 60 DAS

Genotypes : It is clear from evaluation of data presented in Table 4.3 reveals that irrespective of years, the concomitant effect of genotypes significantly influenced DMA at 60 DAS. At this stage CSV 15 produced significantly higher DMA over rest of two genotypes i.e. SCV 1430 and CSH 14. However, genotype SPV 1430 proved their superiority over CSH 14 during first year of experimentation. Similarly, on pooled data basis CSV 15 recorded significantly higher DMA at 60 DAS over SPV 1430 and CSH 14. The corresponding increases by a margin of 11.11 and 12.95 per cent, respectively, while, both these genotypes were at par with each other in this respect.

Plant density : A reference of the data set out in Table 4.3 indicated that lower plant density registered significantly higher DMA per plant over both medium and higher plant densities during both the years of experimentation. Results further indicated that ever increase in plant density significantly reduced DMA plant⁻¹ at 60 DAS stage of crop growth during both the years. On pooled data basis the increases with lower plant population were to the magnitude of 17.50 and 37.65 per cent, respectively over medium and higher plant populations.

Fertility levels : An examination of data presented in Table 4.3 reveals that application of 125 % RDF recorded significantly higher DMA at 60 DAS over rest of the fertility levels tested during both the years of experimentation. The magnitude of increases with 125% RDF were in the order of 7.74, 22.11 and 57.29 per cent, respectively over 100, 75 and 50 % RDF on pooled basis. However, ever reduction in fertility levels upto 50 % RDF significantly reduced the DMA plant⁻¹ at 60 DAS during both the years of experimentation.

Genotypes x fertility levels on DMA at 60 DAS : Data presented in Table 4.3.1 reveals that across the years of study as well as on pooled data analysis ever increase in fertility levels upto 125% RDF significantly increased dry matter accumulation plant⁻¹ with CSV 15 and CSH 14 except CSH 14 during *kharif* 2003 where response was observed only upto 100% RDF. While, genotype SPV 1430 gave the response

upto 100% RDF during couple of years and on pooled analysis. With regards to genotype, CSV 15 responded significantly superior over SPV 1430 and CSH 14 at all the same level of fertility. While, both SPV 1430 and CSH 14 were at par with each other at all same fertility levels during both the years of study and pooled data in dry matter accumulation plant⁻¹ at 60 DAS.

4.2.2.3 DMA at 90 DAS

Genotypes : It is clearly evident from data presented in Table 4.3 that genotype CSV 15 recorded significantly higher dry matter accumulation at 90 DAS over SPV 1430 and CSH 14 during *kharif* 2003 and 2004. While during first year SPV 1430 was at par with CSH 14 produced significantly higher DMA in *kharif* 2004. On pooled data basis, the increases with CSV 15 were of the order of 10.84 and 16.54 per cent over SPV 1430 and CSH 14. SPV 1430 also produced significantly higher DMA per plant by 5.14 per cent over CSH 14 at this stage.

Plant geometry : Data presented in Table 4.3 reveals that lower plant density recorded significantly higher DMA over medium and higher plant densities during both the years of investigation. On pooled data basis, the corresponding increases to the magnitude of 26.52 and 65.43 per cent, respectively. However, 2.2 lac plants ha⁻¹ also proved significantly superior over higher plant density in DMA plant⁻¹ at 90 DAS stage of crop growth.

Fertility levels : Data depicted in Table 4.3 reveals that application of 100 % RDF recorded significantly higher DMA at 90 DAS over both lower levels during both the years of investigation. Further increase in fertility levels failed to show any significant response. On pooled data basis corresponding increases of 100 RDF were in the order of 3.62 and 31.48 per cent, respectively over 75 and 50 %.

4.2.2.4 DMA at harvest

Genotypes : It is evident from data presented in Table 4.3 that genotype CSV 15 recorded significantly higher dry matter accumulation per plant at harvest over SPV 1430 and CSH 14 during both the years of experimentation. On pooled data basis, the magnitude of increases were 7.76 and 7.81 per cent, respectively. However, both SPV 1430 and CSH 14 were at par with each other in this respect at harvest stage of crop.

Plant geometry : Data presented in Table 4.3 reveals that lower plant density recorded significantly maximum DMA per plant over remaining densities during both

the years. On pooled data basis, the corresponding increases to the extent of 25.05 and 63.39 per cent, respectively. Further, medium plant density i.e. 2.2 lac plants ha⁻¹ produced significantly higher DMA per plant over 3.30 lac plants ha⁻¹ during both the years of experimentation.

Fertility levels : Data (Table 4.3) reveals that application of 100 % RDF recorded significantly higher DMA at harvest during 2003 over 50 and 75 % RDF but in *khariif* 2004 fertility response was received upto 125 % RDF in DMA plant⁻¹ at harvest. On pooled data basis, application of 125 % RDF recorded significantly higher in dry matter accumulation plant⁻¹ over 100, 75 and 50 % RDF, respectively. The corresponding increases were of the order of 4.81, 13.88 and 34.48 per cent, respectively.

Genotypes x fertility levels on DMA at harvest : Data presented in Table 4.3.2 reveals that, under fertility levels, maximum dry matter production plant⁻¹ at harvest recorded with 125% RDF in all test genotypes during both the years of study and on pooled analysis basis but it was statistically at par with 100% RDF at all the genotypes. While, 100% RDF was also at par with 75% RDF in DMA plant⁻¹ at harvest with all the genotypes during both the years of experimentation except CSH 14 during *khariif* 2004 and pooled analysis, where, 100% RDF brought about a significant variation over 75% RDF in DMA plant⁻¹ at harvest. While, application of 75% RDF significantly increased dry matter accumulation plant⁻¹ at harvest over 50% RDF in all genotypes. Further, among the genotypes, CSV 15 was proved their superiority over CSH 14 with 50 and 75% RDF levels during both the years of study and on pooled data basis. At 75% level of fertility CSV 15 proved significantly superior over SPV 1430 during second year and combined result basis but it was found at par during first year of study. At both the higher fertility levels i.e. 100 and 125% all the genotypes were at par with one another during both the years and on pooled basis, except 100% RDF. During second year of study where CSV 15 and CSH 14 were produced significantly higher biomass plant⁻¹ over SPV 1430.

4.2.3. Days to 50 % blooming

Genotypes : A critical examination of data (Table 4.4) reveals that genotypes had significant effect on days to 50 % flowering during both the years of experimentation. CSH 14 recorded significantly minimum days to 50 % flowering over SPV 1430 and CSV 15. Both SPV 1430 and CSV 15 were at par with each other in this case during

both the years. The corresponding reduction with genotype CSH 14 was to the magnitude of 6.21 and 7.14 per cent over CSV 15 and SPV 1430 respectively on pooled basis.

Plant geometry : Further, all plant geometries were failed to record any significant influence with one another on duration required by the crop to 50 % blooming.

Fertility levels : An examination of data (Table 4.4) reveals that application of fertility levels from 75 to 125 % RDF reduced days to flowering significantly over 50% RDF during both the years except 75 % RDF during first year of experimentation. However, all the higher doses i.e. 75, 100 and 125 % RDF found statistically at par with one another. Similar results were obtained in pooled analysis both the years in this respect.

4.2.4 Days to maturity

Genotypes : Data presented in Table 4.4 reveals that genotypes had significant effect on days to maturity during both the years of study. SPV 1430 recorded significantly minimum days to maturity over CSH 14 and CSV 15. The corresponding reduction with genotype SPV 1430 were to the magnitude of 5.63 and 20.24 per cent, over CSH 14 and CSV 15, respectively on pooled basis.

Plant geometry : Further, all the plant geometries failed to record any significant variation with one another on days required by the crop to maturity during both the years.

Fertility levels : An examination of data presented in Table 4.4 shows that application of fertility levels from 75 to 125% RDF reduced days to maturity during 2003 but in *kharif* 2004 application of 125% RDF was found statistically superior over 75% RDF but 125% RDF showed non-significant variation with 100% RDF and 100 RDF at par with 75% RDF. While, in case of combined analysis of both the years ever increase in fertility brought about significant variation upto 100% RDF but increase in fertility did not so any positive response.

4.3 YIELD ATTRIBUTES AND YIELD

Data on yield attributes and yield of sorghum crop as influenced by treatments are presented in Table 4.5 and 4.6. The relevant analysis of variance is appended at the end (Appendices X to XIII).

4.3.1 Panicle length

Genotypes : An examination of the data (Table 4.5) indicate that genotypes significantly enhanced the panicle length (cm) during either year of study. Genotype CSV 15 produced significantly more panicle length over SPV 1430 and CSH 14 but both these genotypes did not differ significantly in panicle length during both the years. On pooled data basis, maximum length of panicle was recorded with CSV 15 (28.63 cm) which was 8.65 and 10.58 per cent, higher over SPV 1430 and CSH 14.

Plant geometry : It is evident from the data presented in Table 4.5 that plant geometry significantly affected the panicle length during both the years of investigation. Maximum panicle length was noted with normal plant density i.e. 1.50 lac plants ha⁻¹ which was significantly higher over medium and higher plant densities during both the years. While, 2.20 lac plants ha⁻¹ recorded significantly higher panicle length over 3.30 lac plants ha⁻¹. On the basis of pooled data, 1.50 lac plants ha⁻¹ indicated significantly higher panicle length over medium and higher plant densities and registering 11.16 and 22.25 per cent, respectively. Further, medium plant density was also obtained significantly higher length of panicle over 3.30 pants ha⁻¹. The corresponding increase was 10.25 per cent.

Fertility levels : A further reference of the same table revealed that application of nitrogen and phosphorus levels increased panicle length (cm) per plant significantly with increasing levels of fertility upto 100 % RDF while, further increase in fertility did not increase the panicle length over 100 % RDF during both the years as well as combined result (pooled). On pooled data basis, increases in length of panicle per plant with the application of 75 and 100 % RDF were in the order of 10.58 and 16.81 per cent, respectively over 50 % RDF.

4.3.2 Weight of panicle (g)

Genotypes : Genotypes differed significantly in weight of panicle per plant (Table 4.5) during both the years of experiment and on pooled data. During first year genotype CSH 14 recorded significantly higher weight of panicle per plant over CSV 15 and SPV 1430. Whereas in second year of experimentation CSH 14 recorded panicle weight was statistically at par with CSV 15. While, panicle weight of CSV 15 was at par with SPV 1430 during both the years of experimentation. On pooled data basis, CSH 14 recorded significantly higher weight of panicle over CSV 15 and SPV 1430. The per cent increase was to the magnitude of 3.08 and 5.73, respectively.

Plant geometry : It is evident from the data (Table 4.5) reveals that plant geometry significantly affected weight of panicle per plant during both the years of study. Normal plant density (45 x 15 cm) recorded significantly higher weight of panicle over 2.2 and 3.3 lac plants ha⁻¹ and amounting to increase 8.24 and 21.00 per cent, respectively on pooled data basis. Further, 2.2 lac plants ha⁻¹ also recorded significantly higher weight of panicle over high density during both the years of experiment as well as pooled basis.

Fertility levels : Each increment in fertility level upto 100 % recommended dose of fertilizers significantly increased weight of panicle per plant during both the years of experimentation and on pooled data. However, variation between 100 and 125 % RDF found statistically at par during both the years of study and in pooled analysis. Thus, on pooled data basis application of 100 % RDF improved weight of panicle by 16.31 and 5.97 per cent over 50 and 75 % RDF, respectively.

4.3.3 Grain weight

Genotypes : Genotypes differed significantly in grain weight per panicle (Table 4.5) during both the years of experiment. Genotype CSH 14 recorded significantly higher grain weight per panicle over CSV 15 and SPV 1430 during either years. While, during first year CSV 15 proved significantly superior over SPV 1430 but during second year both were at par with each other. But in pooled analysis CSH 14 reported significantly superior by 5.62 and 10.05 per cent, respectively over CSV 15 and SPV 14.30. Genotype CSV 15 was also proved significantly superior by 4.20 per cent over SPV 1430.

Plant geometry : A critical examination of data (Table 4.5) reveals that plant geometries significantly affect the grain weight of panicle per plant during both the years of experimentation. On pooled basis, low density recorded significantly higher grain weight per panicle over medium and high plant densities and accounting to increases by 8.23 and 21.00 per cent, respectively. Further, data noted that medium plant geometry also recorded significantly higher grain weight per panicle over high density and the increase was 11.79 per cent, respectively.

Fertility levels : A perusal of data (Table 4.5) reveals that across the years of experiment ever increment in fertility levels upto 100 % RDF significantly increased grain weight of panicle. However, variation between 100 and 125 % RDF was found statistically at par with each other during both the years of experimentation and in

pooled analysis. Thus, when compared to 50 and 75 % RDF, application of 100 % RDF increased grain weight per panicle by 18.55 and 7.23 per cent, respectively on pooled basis.

4.3.4 Test weight

Genotypes : Data presented in Table 4.5 reveals that genotype CSH 14 recorded significantly higher in test weight over CSV 15 and SPV 1430 during both the years but remaining both the varieties were found at par with each other in this respect. On pooled data basis, corresponding increases with CSH 14 were by 17.16 and 9.85 per cent, over CSV 15 and SPV 1430, respectively.

Plant geometry : An examination of data (Table 4.5) reveals that plant geometry had significant affect on test weight of sorghum genotypes during both the years of investigation. An increase in plant population from 1.5 lac to 3.3 lac ha⁻¹ significantly decreased test weight of sorghum genotypes. On pooled data basis, lower plant density (recommended for grain purpose i.e. 1.50 lac plants ha⁻¹) recorded significantly higher test weight over medium and higher plant densities and registering 9.59 and 23.67 per cent, respectively. Further, plant geometry 2.2 lac ha⁻¹ was also recorded significantly higher test weight over higher i.e. 3.3 lac plant ha⁻¹ and the corresponding increase was 12.85 per cent, respectively on pooled basis.

Fertility levels : Data presented in Table 4.5 reveals that across the years of experiment increase in fertility level upto 75% RDF increased significantly test weight over 50% RDF. Further, enhanced the level of fertility upto 125% RDF found statistically at par during both the years. On pooled basis, application of 100 and 75% RDF recorded significantly higher test weight over 50% RDF and registering 8.45 and 6.58 per cent, respectively.

4.3.5 Grains panicle⁻¹

Genotypes : A perusal of data on grains panicle⁻¹ presented in Table 4.5 indicate that number of grains panicle⁻¹ was affected significantly due to different genotypes during both the years of experimentation. Results showed that CSH 14 recorded maximum number of grains panicle⁻¹ but it was at par with CSV-15 while superior over SPV 1430 during both the years. Whereas, SPV 1430 recorded least number of grains panicle⁻¹ during both the years of experiment but, it was at par with CSV-15 during first year of experimentation in this respect.

Plant geometry : Data presented in Table 4.5 reveals that grains per panicle reduced significantly with increase number of plant ha^{-1} from 150,000 (recommended spacing 45 x 15 cm) to 333,000 plants ha^{-1} that attained the lowest number of grains panicle $^{-1}$ during both the years of experimentation and on pooled result except 2.2 lac plants ha^{-1} during first year which was at par with normal plant density in this respect. The per cent reduction in grains panicle $^{-1}$ with medium and higher plant densities were to the magnitude of 5.70 and 12.44, respectively over normal plant density on pooled basis.

Fertility levels : It is explicit from data (Table 4.5) that application of 100 % RDF recorded significantly superior in number of grains per panicle over both lower fertility levels during both the years of experimentation. On pooled data basis, the per cent increases in grain panicle $^{-1}$ with 100% RDF were to the tune of 5.65 and 9.22 per cent, respectively over 75 and 50% RDF. However, further increase in fertility level from 100 and 125% RDF did not show statistically variation with each other during both the years of investigation.

4.3.6 Grain yield (q ha^{-1})

Genotypes : An examination of data presented in Table 4.6 reveals that growing of genotype CSH 14 brought about significantly higher grain yield production over CSV 15 and SPV 1430 during both the years of experimentation and on combined analysis of both the years. Further, CSV 15 was registered analytically better than SPV 1430 in grain yield. On the basis of combined results of both the years, genotype CSH 14 (41.37 q ha^{-1}) enhanced the grain yield significantly over CSV 15 and SPV 1430. The corresponding increases were to the tune of 21.61 and 36.62 per cent, respectively. Further, examination of data revealed that CSV 15 obtained 12.35 per cent higher grain yield as compared to SPV 1430 (30.28 q ha^{-1}).

Plant geometry : A perusal of data presented in Table 4.6 reveals that plant geometry significantly affected the grain yield during 2003, 2004 and on pooled basis. Normal density i.e. 1.5 lac plants ha^{-1} recorded significantly higher grain yield over rest of the higher plant densities. It is clear from the data that ever increase in plant density significantly reduced the grain yield during both the years as well as on combined analysis of both the years. On the basis of pooled data, reductions with medium and higher plant densities were by 14.83 and 65.07 per cent over normal plant density in this parameter. Medium plant density also brought about significantly higher grain

yield over 3.30 lac plants ha⁻¹ during both the years and gave 43.75 per cent higher grain yield on pooled basis.

Fertility levels : Further, data in Table 4.6 showed that ever increment in fertility level upto 100% RDF significantly increased grain yield. Whereas, variation between 100 and 125% RDF found statistically at par during both the years of study and in pooled analysis. Thus, when compared to 50 and 75% RDF, application of 100% RDF (80 kg N + 40 kg P₂O₅ ha⁻¹) increased grain yield by 14.95 & 37.02; 14.97 & 40.83 and 14.97 & 38.96 per cent, respectively during 2003, 2004 and on pooled basis. Further, application of 75% RDF (60 kg N + 30 kg P₂O₅ ha⁻¹) obtained significantly higher grain yield over 50% and registering 19.21, 22.49 and 20.87 per cent, respectively during 2003, 2004 and on pooled basis.

Genotypes x fertility levels on grain yield (q ha⁻¹) : Data presented in Table 4.6.1 reveals that across the years of experimentation as well as on pooled basis, maximum grain yield was recorded by CSH 14 alongwith 100% RDF. Further, under all the fertility levels, the significant increase in grain yield recorded under CSH 14 as compared to CSV 15 and SPV 1430. Similarly, CSV 15 also proved significantly superior over SPV 1430 at each same level of fertility during both the years of study and pooled analysis except 75% RDF during *kharif* 2003 where both were at par each other. With regards to fertility levels, ever increase in fertility levels from 50 to 100% RDF significantly responded at all the three test genotypes in grain yield during both the years and on pooled basis. Further increase in fertility level from 100 to 125% RDF did not show any positive response with any of genotypes during whole period of studies as well as combined results.

4.3.7 Fodder yield (q ha⁻¹)

Genotypes : An examination of data presented in Table 4.6 shows that genotype CSV 15 indicated significantly higher in dry fodder production over SPV 1430 and CSH 14 during both the years of investigation. Further, SPV 1430 noted significantly superior in dry fodder yield over CSH 14 during both the years of experimentation. On the basis of pooled data genotype CSV-15 significantly enhanced the dry fodder production by 9.08 and 32.59 per cent higher over SPV 1430 and CSH 14. While, SPV 1430 also proved significantly superior over CSH 14 and produced 21.55 per cent higher dry fodder yield over CSH 14 (100.68 q ha⁻¹).

Plant geometry : It is evident from the data (Table 4.6) that higher plant density i.e. (3.3 lac plants ha⁻¹) produced significantly higher fodder yield over lower and medium plant densities during both year except medium density during first year of experimentation which was at par. Data further indicated that plant geometry 45 x 10 (2.2 lac plants ha⁻¹) obtained significantly higher dry fodder yield over 45 x 15 cm (normal plant geometry i.e. 1.50 lac plants ha⁻¹) during both the years. On the basis of combined result ever increases in plant density significantly enhanced dry fodder production upto 3.3 lac plant ha⁻¹. Higher density increased the fodder yield by 23.67 and 5.75 per cent over lower and medium densities of plant ha⁻¹. Further, medium plant density also proved significantly superior by 16.95 per cent over low density.

Fertility levels : It can be inferred from the data in Table 4.6 that during both the years and combined effect ever increase in fertility levels from 50% to 125% RDF significantly increased dry fodder yield except second year of experimentation where response of fertility was observed only upto 80 kg N + 40 kg P₂O₅ ha⁻¹ i.e. 100% RDF. On the basis of pooled analysis application of 125 % RDF noted 27.06, 14.24 and 5.85 per cent higher dry fodder over 50, 75 and 100 % RDF. Further, 100% RDF level of fertility also produced 20.04 and 7.93 per cent higher dry fodder yield over 50 & 75 % RDF.

4.3.8 Biological yield

Genotypes : It is clear from evaluation of the data (Table 4.6) indicate that across the years of study genotypes had significant effect on biological yield. Maximum biological yield was obtained with genotype CSV 15 which was significantly higher over rest of two genotypes tested. However, genotype SPV 1430 also proved analytically superior over CSH 14. Similar results were obtained with pooled analysis of both the years. On the basis of combined result CSV 15 gave 9.73 and 17.92 per cent higher biological yield over SPV 1430 (152.66 q ha⁻¹) and CSH 14 (142.06 q ha⁻¹). Further, SPV 1430 recorded significantly higher biological yield over CSH 14 and accounting to 7.46 per cent higher on pooled basis, respectively.

Plant geometry : Data presented in Table 4.6 reveals that during both the years of experimentation biological yield significantly influenced by plant densities. During both the years of experimentation medium plant density proved significantly superior over normal plant density while, higher plant density reduced the biological yield over medium plant density. On pooled analysis basis medium plant density proved

significantly superior by 8.30 and 2.75 per cent over normal and higher plant densities.

Fertility level : A perusal of data (Table 4.6) reveals that during first year and pooled analysis of studies ever increase in fertility levels from 50% to 125 RDF significantly increased biological yield but in second year response of fertility was noted upto 100% RDF in biological yield. In combined analysis, application of 125% RDF produced significantly higher biological yield which was 29.86, 14.64 and 4.66 per cent, higher over 50, 75 and 100% RDF. While, 100% RDF also proved significantly superior over 50 and 75% RDF and gave 24.09 and 9.54 per cent higher biological yield, respectively.

4.3.9 Harvest index

Genotypes : An examination of data presented in Table 4.6 reveals that genotype CSH 14 brought about significantly higher harvest index over rest of two genotypes of sorghum during both the year of study and pooled result. While these two genotype i.e. CSV 15 and SPV 1430 were failed to show any significant variation with each other. On pooled data basis CSH 14 (29.32 g) recorded significantly higher harvest index over CSV 15 (20.45) and SPV 1430 (19.86). The corresponding increases were by 43.37 and 47.63 per cent, respectively.

Plant geometry : Further, data showed that harvest index reduced significantly with increasing plant population during both the years of experimentation and in combined result. The increases with normal plant density were of the order of 25.22 and 75.25 per cent, respectively over medium and high plant densities. Whereas, medium plant density significantly improved harvest index (HI) over high plant density and representing 39.75 per cent higher on pooled data basis.

Fertility levels : A perusal of data (Table 4.6) reveals that across the years of experiment application of 75% RDF level of fertility significantly improved the HI over 50% RDF. Further increase in fertility levels did not show any statistical variation with one another in this respect during both the years. But when result of two years was pooled together 100% RDF showed significant variation over 75% RDF. Thus, application of 100% RDF increased HI by 11.31 and 4.47 per cent, over 50 and 75% RDF, respectively.

4.4 NUTRIENT CONTENT

The estimates of nutrient content (N and P) in grain and fodder at harvest of the crop under the influence of various treatments are presented in Table 4.7 and the respective analysis of variance are presented in Appendix XIV to XV.

4.4.1 Nitrogen content

4.4.1.1 In grain

Genotypes : It is explicit from data (Table 4.7) that among genotypes tested CSH 14 brought about significantly higher in N content in grain at harvest over rest of the genotypes i.e. CSV 15 and SPV 1430, while, both were statistically at par with each other during both the years of study. On pooled analysis basis similar results were obtained and increases with CSH 14 were by 1.39 and 1.38 per cent over CSV 15 and SPV 1430, respectively.

Plant geometry : Across the years, plants under the influence of plant densities had significantly differ N content in grains at harvest. Nitrogen content in grains showed significant improvement with normal plant density over higher and medium densities. While, ever increase in plant density upto 3.3 lac plant ha⁻¹ significantly decreased the N content in grains during both the years of experimentation and on pooled basis.

Fertility levels : Further, data in Table 4.7 showed that graded increase the fertilizer application from 50 to 125% RDF significantly increased N content in grain. On pooled basis, application of 125% RDF recorded nitrogen content in grain (1.55%) which was significantly enhanced over 50, 75 and 100% RDF by 9.15, 3.33 and 1.98 per cent respectively. However, application of 100% RDF also significantly improved N content in grains by 7.04 and 1.33 per cent over 50 and 75% RDF, respectively.

Genotypes x fertility levels on nitrogen content in grain at harvest : The interaction effect of genotypes and fertility levels with regards to nitrogen content in grains at harvest in 2003, 2004 and on pooled basis. Data presented in Table 4.7.1 reveals that, when sowing was done with CSH 14, the response to fertility levels was noted only upto 125% RDF during *kharif* 2003 and pooled basis. But in *kharif* 2004 response was noted only upto 100% RDF. However, it was found at par to 75% and 125% RDF. In combined results ever increase in fertility increased the N content in grains in case of genotype CSH 14. With regards to other genotypes i.e. CSV 15 and SPV 1430 responded to fertility levels only upto 75% RDF which were statistically superior over 50% RDF in N content in grains during *kharif* 2003 and 2004 but when

comprised in combined result higher N content was noted with 125% RDF but it was found statistically at par with 100% RDF. With regards to genotypes, CSH 14 proved statistically superior over both CSV 15 and SPV 1430 at all the same fertility levels during both the years of experimentation as well as pooled results. While, both genotypes i.e. CSV 15 and SPV 1430 were at par with each other in N content in grains at same fertility levels during both the years of study.

4.4.1.2 In fodder

Genotypes : Data presented in Table 4.7 reveals that the effect of genotypes on per cent N content in fodder was varied significantly during both the years of experiment and on pooled basis. CSH 14 resulted significantly higher N content in fodder over CSV 15 and SPV 1430 during 2003, 2004 and on pooled basis. While, genotype CSV 15 also recorded higher N content in dry fodder over SPV 1430 during second year of study and on pooled analysis results basis.

Plant geometry : As per the N content in grains similar results were obtained with N content in dry fodder at harvest. Results showed that increasing plant population recorded significant reduction in N content in fodder during both the years of experimentation and on pooled basis. Normal plant geometry recorded significantly higher N content in fodder over medium and higher plant population respectively and recorded 0.530, 0.530 and 0.530 per cent N content during 2003, 2004 and on pooled basis at normal plant density ($1.50 \text{ lac plants ha}^{-1}$).

Fertility levels : Similarly, ever increase in fertilizer application upto 125% RDF significantly improved N content in fodder during both the years. On pooled analysis basis the increases were by 23.42, 12.13 and 5.82 per cent over 50, 75 and 100% RDF, respectively.

4.4.2 Phosphorus content

4.4.2.1 In grain

Genotypes : An examination of data presented in Table 4.7 that growing of genotype CSH 14 brought about significantly higher P concentration in grains at harvest over both the remaining genotypes during both the years of investigation and on pooled analysis basis. However, CSV 15 genotype had more P content over SPV 1430 during *kharif* 2004 and combined result but in *kharif* 2003 both were at par with each other.

Plant geometry : A perusal of data (Table 4.7) reveals that across the years of study, normal plant geometry indicated significantly higher phosphorus content in grains at harvest over rest of two plant densities. Whereas, in medium density P content was noted significantly higher over high plant density during both the years of study.

Fertility levels : Data presented in Table 4.7 indicate that ever increasing dose of fertilizer application from 50% to 125% RDF significantly increased P content in grain at harvest during both the years of experimentation. On pooled data basis application of 125% RDF recorded phosphorus content in grains by 15.74, 7.31 and 3.53 per cent higher over 50, 75 and 100% RDF respectively.

4.4.2.2 In fodder

Genotypes : Data presented in Table 4.7 reveals that the effect of genotype on P content in fodder with regards to genotypes was significantly different during both the years of experiment and on pooled basis. Genotype CSH 14 resulted significantly higher P content in dry fodder over CSV 15 and SPV 1430. While, genotype CSV-15 significantly superior P content over SPV 1430 during *khariif*, 2003, 2004 and on pooled basis in this respect.

Plant geometry : An examination of data (Table 4.7) revealed that increasing plants population from 1.50 to 3.30 lac plants ha⁻¹ resulted significant reduction in P content in fodder. Normal plant geometry proved their superiority in P content in fodder over medium and higher plant densities. The increases were by 3.41 and 7.96 per cent, respectively.

Fertility levels : Fertilizer application upto 125% RDF significantly improved P content in fodder. In combined analysis, application of 125% RDF obtained P content (0.2067 per cent) which was significantly higher over rest of the lower doses of fertility levels. The increases were by 11.73, 8.79 and 4.24 per cent over 50, 75 and 100% RDF, respectively.

Genotypes x fertility levels on P content in fodder at harvest : Data presented in Table 4.7.2 reveal that during 2004 and on pooled basis, P content in fodder significantly influenced at harvest by combined effect of genotypes and fertility levels. It is clear from data that lowest P content was observed under SPV 1430 with 50% recommended dose of fertilizers during 2004 and on pooled basis. The highest P content was noted under CSH 14 along with 125% RDF. While, CSH 14 contains significantly higher P content at each level of fertility upto 100% RDF over CSV 15

and SPV 1430 during *kharif* 2004 and pooled results. Both these genotypes were at par with each other in this respect.

Table 4.7.2. Interaction effect of genotypes and fertility levels on phosphorus content (%) in fodder

Fertility levels	Genotype					
	2004			Pooled		
	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14
50% RDF	0.18	0.17	0.20	0.183	0.172	0.194
75% RDF	0.19	0.19	0.20	0.192	0.186	0.200
100% RDF	0.20	0.20	0.21	0.199	0.196	0.205
125% RDF	0.21	0.21	0.21	0.206	0.204	0.209
		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)
Fertility levels at same genotype		0.003	0.008		0.002	0.005
Genotypes at same or different levels of fertility		0.003	0.009		0.002	0.006

Genotypes x plant geometry on P content in fodder at harvest : It is inferred from the data presented in Table 4.7.3 that P content in fodder significantly influenced by combined effect of genotypes and plant geometry during both the years as well as on pooled basis. Further, irrespective to the genotype, the increase in plant density from 45 x 15 cm to 30 x 10 cm significantly decrease the phosphorus content in fodder with all the test genotypes during the years of experimentation and on pooled basis. The maximum P content in fodder was observed under 45 x 15 plant geometry with CSH 14 which was found to be significantly superior over rest of the combinations.

4.5 NUTRIENT UPTAKE

The influence of various treatment on uptake of nutrients (N and P) by grain, fodder and total uptake are reported in Table 4.8 and 4.9. The analysis of variance for each estimate are furnished in Appendices XVI to XIX.

4.5.1 Nitrogen uptake

4.5.1.1 By grain

Genotypes : An examination of data (Table 4.8) reveal that grain produced due to genotype CSH 14 accumulated significantly higher N over CSV 15 and SPV 1430 during both the years of study and on pooled analysis basis. The accumulation increases were of the order of 50.79 and 71.76 per cent, respectively. While, genotype CSV 15 also proved significantly superior in N uptake by grain over SPV 1430.

Plant geometry : It is explicit from the data given in Table 4.8 indicate that normal plant geometry recorded significantly higher nitrogen uptake by grain over medium and higher plant densities. Further, medium density also accumulated statistically higher N content over higher plant density during both the years of experiment. The per cent increase in nitrogen uptake by grain at harvest with normal plant population was to the magnitude of 28.87 and 82.38, respectively over medium and high plant population on pooled basis.

Fertility levels : A critical examination of data presented in Table 4.8 shows that application of fertility levels upto 100% RDF significantly improved the nitrogen uptake by grain at harvest during both the years of experimentation. The increases were by to the magnitude of 49.68 and 16.75 per cent, on pooled basis. However, further increase in fertility level from 100 to 125% RDF was failed to record any significant variation.

Genotypes x fertility levels on nitrogen uptake by grain : A perusal of data depicted in Table 4.8.1 reveals that nitrogen uptake by grain significantly influenced by combined effect of genotypes and fertility levels during both the years and on pooled basis. Among the genotypes, CSH 14 consumed significantly higher N by grain at all the fertility levels over CSV 15 and SPV 1430 while, CSV 15 also significantly higher N uptake in grain at all the same fertility levels during *khari* 2003 and 2004 and combined results. Among the fertility levels, genotypes CSV 15 and SPV 1430 significantly responded to N uptake by grain upto ever increase in fertility levels upto 100% RDF during both the years of investigation. While, CSH 14 was statistically increased N uptake by grain with ever graded increase in fertility levels upto 125% RDF during years of study.

Genotypes x plant geometry in N uptake by grain at harvest : It is evident from data (Table 4.8.2) that across the years and on pooled basis nitrogen uptake by grain showed significant response with genotype CSH 14 at normal plant density i.e. 1.5 lac

plants ha⁻¹ (45 x 15 cm). Further, irrespective to the genotype, the reduction in plant geometry from 45 x 15 cm to 30 x 10 cm significantly decreased the nitrogen uptake in grain during the both the years and on pooled basis. The maximum N uptake by grain was observed under 45 x 15 plant density under CSH 14 which was found to be significantly superior over rest of the combinations. Minimum N uptake by grain at harvest was obtained under SPV 1430 in combination with 30 x 10 cm plant geometry.

4.5.1.2 By fodder

Genotypes : Data presented in Table 4.8 reveals that fodder produced due to genotype CSV 15 accumulated significantly higher N content over SPV 1430 and CSH 14 while both these genotypes were act as similar response in N uptake during both the years of study. On pooled analysis basis, corresponding increases were made to the magnitude of 11.40 and 16.13 per cent, respectively.

Plant geometry : Further, none of the plant population produced their superiority with one another in sorghum fodder during period of studies.

Fertility levels : Ever increase in application of NP fertilization upto 125% RDF significantly increased nitrogen uptake by fodder at harvest across the years of study. On combined results, application of 125% RDF significantly enhanced nitrogen uptake by 57.83, 28.56 and 12.30 per cent over 50, 75 and 100% RDF respectively.

4.5.1.3 Total nitrogen uptake by the crop

Genotype : A reference to data given in Table 4.8 reveals that sorghum crop produced due to genotype CSH 14 accumulated significantly higher total nitrogen uptake over CSV 15 and SPV 1430. While, CSV 15 also N uptake significantly higher over SPV 1430 during both the years of investigation. The corresponding increases to the magnitude of 14.45 and 28.74 per cent, respectively on pooled basis.

Plant geometry : It is explicit from the data presented in Table 4.8 indicate that normal plant geometry recorded significantly higher total nitrogen uptake by crop over remaining two densities during both the years of study. The per cent increase in total nitrogen uptake by crop at harvest were by the margin of 8.24 and 31.52, respectively over medium and higher plant densities on pooled basis. However, medium plant geometry also recorded significantly higher total nitrogen uptake by the

sorghum crop over high plant geometry and amounting to increase 21.51 per cent, respectively on pooled basis.

Fertility levels : Application of 125% RDF recorded significantly maximum total nitrogen uptake over 50, 75 and 100% RDF during both the years and on pooled result basis. The per cent increases were to the magnitude of 56.23, 24.57 and 7.78 respectively over 50, 75 and 100% RDF, on pooled basis respectively. Further, reduction in fertility levels upto 50% RDF significantly reduced the N uptake by the crop.

Genotypes x fertility levels on total N uptake by crop : An examination of data presented in Table 4.8.3 reveals that application of 125% RDF alongwith genotype CSH 14 significantly increased the total N uptake by the crop at harvest over the rest of combinations of genotypes and fertility level during both the years of study and on pooled basis. While, significantly minimum total N uptake by crop was observed with genotype SPV 1430 at 50% RDF during couple of years of study. Further, ever increase in fertility levels significantly increased total N uptake with all genotypes.

Genotypes x plant geometry on total nitrogen uptake by crop : Data presented in Table 4.8.4 indicate that total nitrogen uptake by crop showed significant response with plant geometry in combination with genotypes. On pooled basis, maximum total N uptake by crop was noted under influence of CSH 14 at normal plant density which was found significantly higher over rest of the combinations. Minimum total N uptake by the crop at harvest was obtained under SPV 1430 in combination with high plant density.

Table 4.8.4. Interaction effect of genotypes and plant geometry on total nitrogen uptake (kg ha⁻¹) by crop (Pooled)

Genotypes	Plant geometry		
	45 x 15 cm	45 x 10 cm	30 x 10 cm
CSV 15	120.919	113.246	94.473
SPV 1430	109.021	100.266	82.873
CSH 14	141.455	129.641	105.038
		SEm±	CD (P=0.05)
Plant geometries at same genotype		1.575	4.536
Genotypes at same or different plant geometry		1.590	4.590

4.5.2 Phosphorus uptake

4.5.2.1 By grain

Genotypes : A reference of data given in Table 4.9 show that genotype CSH 14 significantly enhanced P uptake by grain over CSV 15 and SPV 1430. However, genotype CSV 15 also brought about significantly positive response in P uptake by grain over SPV 1430 during both the years of study. On pooled data basis CSH 14 significantly increased by 28.91 and 49.58 per cent over genotypes CSV 15 and SPV 1430 while CSV 15 was 16.03 per cent superior in phosphorus uptake by SPV 1430.

Plant geometry : Data presented in Table 4.9 reveals that the highest uptake of phosphorus by grain was recorded with the recommended plant geometry i.e. 45 x 15 cm whereas, the least uptake was noted with high plant density during both the years of study. The percent increase with normal plant population was of the order of 19.03 and 79.06 per cent over medium and high plant densities, respectively on pooled basis. While, medium plant density was also proved significantly superior over high density during both the years as well as on pooled basis.

Fertility levels : Data further showed that progressive increase in fertility level was obtained significantly upto 100% RDF during 2003 but in *kharif* 2004 it was observed upto 125% RDF in case of P uptake by grain. Thus, on the basis of pooled analysis compared to 50, 75 and 100% RDF, application of 125% RDF registered increases of 60.85, 24.00 and 4.04 per cent, respectively.

Genotypes x fertility levels on P uptake by grain : A critical examination of data (Table 4.9.1) indicate that P uptake by grain at harvest significantly influenced by combined effect of genotypes and fertility levels during both the years and on pooled result basis. All the genotypes were responded in P uptake by grain significantly to fertility levels upto 100% RDF during both the years and combined results. However, significantly maximum P uptake by grain was observed with genotype CSH 14 at all same fertility levels over genotypes SPV 1430 and CSV 15 in this regard.

Genotypes x plant geometry on P uptake by grain : Data presented in Table 4.9.2 reveals that P uptake by grain at harvest significantly influenced by combined effect of genotypes and plant densities. The highest increases of 173.89 and 133.41 per cent were obtained under combined effect of CSH 14 at normal plant density over SPV 1430 and CSV 15 at high plant population ha⁻¹, respectively on pooled data basis.

Table 4.9.2. Interaction effect of genotypes and plant geometry on P uptake (kg ha⁻¹) by grain (Pooled)

Genotypes	Plant geometry		
	45 x 15 cm	45 x 10 cm	30 x 10 cm
CSV 15	13.740	11.645	7.614
SPV 1430	11.848	10.110	6.489
CSH 14	17.772	14.676	10.102
		SEm±	CD (P=0.05)
Plant geometries at same genotype		0.266	0.765
Genotypes at same or different plant geometry		0.221	0.639

4.5.2.2 By fodder

Genotypes : A perusal of data (Table 4.9) revealed that genotype CSV 15 absorbed significantly higher P uptake by fodder over SPV 1430 and CSH 14. While, SPV 1430 also brought about significant improvement in P uptake over CSH 14 during both the years of experimentation. On combined analysis, increases with CSV 15 were noted by 11.75 and 28.36 per cent over SPV 1430 and CSH 14, respectively.

Plant geometry : An examination of data reveals that the higher uptake of phosphorus by fodder recorded with both the higher plant populations over normal plant population ha⁻¹ but both the higher populations did not show any significant variation with each other in this respect.

Fertility levels : Further, progressive increase in fertility level upto 125% RDF significantly increased P uptake by fodder during the years of experimentation. Thus, compared to 50, 75 and 100% RDF, application of 125% RDF registered increases by 44.24, 22.95 and 9.25 per cent, respectively on pooled basis.

4.5.2.3 Total phosphorus uptake by crop

Genotypes : An examination of data presented in Table 4.9 reveals that sorghum crop produced due to genotype CSV 15 uptake significantly higher total phosphorus uptake by crop over CSH 14 and SPV 1430 during both the years of study. The corresponding increase to the margin of 7.48 and 12.95 per cent, respectively on pooled basis. However, variation between CSH 14 and SPV 1430 with regards to total

P uptake was found statistically at par during 2003 but in 2004 and in pooled analysis CSH 14 proved significantly superior over SPV 1430 in this respect.

Plant geometry : It is clear from the data presented in Table 4.9 reveals that normal and medium plant geometries recorded significantly higher over high plant density but proved statistically at par with each other in total phosphorus uptake by crop during both the years of experimentation.

Fertility levels : An application of 125% RDF obtained significantly maximum total phosphorus uptake by the crop over rest of the levels of fertility while ever decrease in fertility level decreased total phosphorus uptake by crop during the years of investigation and on pooled basis. On the basis of combined analysis of data, the per cent increases with 125% RDF were of the order of 49.34, 23.30 and 7.45 over 50, 75 and 100% RDF, respectively.

4.6 PROTEIN CONTENT AND PROTEIN YIELD

Data on protein content and protein yield in grain at harvest of sorghum under the influence of various treatments are presented in Table 4.10 and respective analysis of variance have been furnished in Appendices XX to XXI.

4.6.1 Protein content

Genotypes : An examination of data depicted in Table 4.10 reveals that CSH 14 significantly indicated highest protein content in grain during both the years of study and on pooled basis over CSV 15 and SPV 1430. While, genotype CSV 15 gave significantly at par result with SPV 1430 during first year of experimentation and pooled analysis but in second year it was proved statistically better than SPV 1430 in protein content. On pooled data basis, protein content in CSH 14 was 10.77 as compare to 8.72 and 8.60 per cent under CSV 15 and SPV 1430, respectively.

Plant geometry : Significant reduction in protein content of grain was recorded with increasing in plant geometry from 45 x 15 cm to 30 x 10 cm. While, medium plant density was also proved significantly superior over higher density during both the years of investigation and on pooled basis.

Fertility levels : Further, significant increase in protein content of grain was recorded at 125% RDF during both the years of study over remaining levels tested but fertility levels 75 and 100% RDF did not show any significant variation during the years of study. While, in case of pooled analysis of both the years ever increase in fertility

levels from 50 to 125% RDF significantly increased protein content in grains. The increases with 125% RDF were by 9.83, 3.74 and 2.10 per cent over 50, 75 and 100% RDF, respectively.

Genotypes x fertility levels on protein content in grain : Data presented in Table 4.10.1 reveals that protein content in grain at harvest significantly influenced by combined effect of genotypes and fertility levels. Response of fertility was observed upto 75% RDF with CSV 15 and SPV 1430 during both the years and pooled data. While, in case CSH 14 significant response was noted upto 125% RDF in 2004 and in pooled basis but in *kharif* 2003 significant effect was noted upto 100% RDF in protein content in grain. Maximum protein content was recorded under CSH 14 alongwith 125% RDF, which was significantly higher over rest of the combinations of each year.

4.6.2 Protein yield

Genotypes : An assessment of data given in Table 4.10 reveals that grain produced due to genotype CSH 14 accumulated significantly highest protein yield over CSV 15 and SPV 1430 during both the years of study and on pooled basis. The corresponding increase were of the magnitude of 50.80 and 71.78 per cent, respectively on pooled basis. Further, data reported that CSV 15 recorded significantly higher protein yield over SPV 1430 during both the years and registering 13.91 per cent higher over SPV 1430 on pooled basis.

Plant geometry : It is explicit from the data presented in Table 4.10 shows that normal plant geometry 45 x 15 cm recorded significantly higher protein yield by grains over 45 x 10 cm and 30 x 10 cm during both the years of study. The per cent increases in protein yield in grain was to the magnitude of 20.87 and 82.40 per cent, respectively on pooled basis. While, medium plant geometry 45 x 10 cm also recorded significantly higher protein yield over high plant geometry by a margin of 50.90 per cent on pooled basis.

Fertility levels : Further, application of fertility levels significantly improved the protein yield produced by grains at harvest during both the years of experimentation. Application upto 100% RDF recorded significantly higher protein yield over 50 and 75% RDF, but further increment in fertility did not effect on protein yield significantly during both the years of experimentation. While, in pooled analysis the response of fertility was noted upto 125% RDF. The increase with 125% RDF were

by 54.50, 20.52 and 3.23 per cent over 50, 75 and 100% RDF, respectively in this respect.

Genotypes x fertility levels on protein yield : Data presented in Table 4.10.2 reveals that genotypes CSV 15, SPV 1430 and CSH 14 produced significantly higher protein yield at 100% RDF over 50 and 75% RDF during both the years and on pooled basis. While, further increase in fertility levels brought about non significant in protein yield in CSV 15 and SPV 1430 during the years of experimentation. Further, in case of CSH 14 fertility response was observed upto highest dose of fertilizers i.e. 125% RDF in protein yield of grain which was significantly higher rest of the genotypes at any of the fertility levels during both the years as well as on pooled basis.

Genotypes x plant geometry on protein yield : Data presented in Table 4.10.3 reveals that protein yield of grain at harvest significantly influenced by combined effect of genotypes and plant geometry. Further, genotypes CSV 15, SPV 1430 and CSH 14 produced significantly higher protein yield at normal plant density over remaining plant densities during 2003, 2004 and on pooled basis. On pooled basis, maximum protein yield was obtained with CSH 14 at normal plant density (45 x 15 cm crop geometry) which was significantly superior over rest of the combinations. Significantly minimum protein yield was obtained at higher plant population with genotype SPV 1430 during both the years of study and on combined results basis.

4.7 NUTRIENT STATUS OF SOILS

The estimates of available nitrogen, phosphorus and potassium status of soil after harvest of sorghum crop under the influence of genotypes, plant geometry and fertility levels are presented in Table 4.11 an analysis of variance is given at the end (Appendix XXII to XXIII).

4.7.1 Available nitrogen

Genotypes : It is clear from the data (Table 4.11) reveals that test genotypes had significant effect on available nitrogen status of soil after harvest of sorghum during both the years. Genotype CSH 14 extracted significantly more nitrogen from the soil in comparison to remaining two genotypes i.e. CSV 15 and SPV 1430 during the course of investigation of two years, while, both these genotypes were at par with each other in this respect. On pooled basis, CSH 14 extracted 4.24 and 4.87 per cent higher available nitrogen from soil over CSV 15 and SPV 1430, respectively.

Plant geometry : It is inferred from the Table 4.11 that high plant density extracted high nutrient content in nitrogen from the soil in comparison to lower plant populations. After analysis of soil it can be observed that high plant density had significantly low available N in soil after harvest the crop. Normal plant population obtained significantly higher available N status of soil as compared to medium and high plant densities (45 x 10 and 30 x 10 cm) during both the years. The per cent increases in available N status in soil after harvest the sorghum with normal plant population ha⁻¹ was to the magnitude of 5.26 and 16.27 per cent, respectively on pooled basis. Further, plant geometry 45 x 10 cm also recorded significantly higher available nitrogen status of soil over higher plant geometry by 10.45 per cent on pooled basis.

Fertility levels : An examination of data (Table 4.11) revealed that ever increases in application of fertility levels upto 100% RDF significantly improved the available N status of soil after harvest the crop during first year of experiment and pooled analysis of both the years. While, in second year, response of fertility was noted only upto 75% RDF. During this year 100% RDF had no significant response in available N in soils after harvest of sorghum crop. On pooled basis, 100% RDF showed 6.80 and 3.02 per cent higher available N content in soil after harvest of crop.

4.7.2 Available phosphorus

Genotypes : Data depicted in Table 4.11 shows that genotypes had significant effect on available P status of soil after harvest the crop during both the years of study. Among the genotypes CSH 14 removed significantly maximum available phosphorus in soil after harvest of sorghum crop over rest of the two genotypes i.e. CSV 15 and SPV 1430. While, genotype SPV 1430 proved significantly minimum P remover from the soil. On pooled basis, significantly maximum available P was obtained with this genotype SPV 1430 which was 3.04 and 6.09 per cent higher over CSV 15 and CSH 14.

Plant geometry : As similar to N, available P content in soil after harvest of sorghum crop was recorded significantly higher with normal plant population over rest of two higher plant populations and ever increase in plant ha⁻¹ available P was decreased significantly during both the years as well as pooled analysis of data. On pooled data basis, the per cent increases in available P status in soil after harvest the crop with

normal plants ha^{-1} was of the order of 3.88 and 11.69 per cent, over medium and higher plant populations ha^{-1} .

Fertility levels : A critical examination of data presented in Table 4.11 revealed that application of fertility levels significantly improved the available P status of soil after harvest the crop upto 100% RDF during 2003 and 2004. Application of 100% RDF recorded significantly higher available P status of soil over 50 and 75% RDF and registering to increases 8.08 and 3.28 per cent, respectively on pooled basis. However, variation between 100% and 125% found statistically at par during both the years and on pooled data basis.

4.7.3 Available potassium

Genotypes : The available K status in soil after harvest the crop was not significantly affected by genotypes during both the years of study as well as on pooled basis.

Plant geometry : Data (Table 4.11) shows that plant geometry had significant effect on available K status in soil during both the years of study. The available K in soil after harvest was higher with normal plant populations ha^{-1} . Which was 3.01 and 4.41 per cent higher over medium and high plant population, respectively on pooled basis. However, both the higher populations did not differ significantly with each other during the period of study in soil after the harvest of crop.

Fertility levels : Application of N and P fertilization as 75% RDF significantly responded available potassium status of soil during the period of study as well as combined status of data. Further, increased of fertility levels did not influence available K status of soil after harvest of sorghum crop during any of the year of investigation.

4.8 ECONOMIC EVALUATION OF TREATMENTS

Data on economic evaluation of treatments of net monetary returns and B:C ratio are presented in Table 4.12. The respective analysis of variance and details of calculations are furnished in Appendices XXIV to XXV.

4.8.1 Net returns

Genotypes : It can be inferred from the data depicted in Table 4.12 reveals that genotype had significant effect on net returns (Rs ha^{-1}) during both the years of study. Among the genotypes, CSV 15 recorded significantly higher net returns ($\text{Rs } 23434, 24436 \text{ and } 23935 \text{ ha}^{-1}$, respectively during 2003, 2004 and on pooled basis) over CSH

14 and SPV 1430, respectively. While test hybrid CSH 14 proved significantly superior over SPV 1430 in net monetary returns during both the years of study and combined analysis of two years. On the basis of pooled analysis genotype CSV 15 obtained Rs 2990 and 1042 ha⁻¹ higher over SPV 1430 and CSH 14, respectively. Further, CSH 14 also earned Rs 1948 ha⁻¹ higher over SPV 1430.

Plant geometry : It is clear from the data presented in Table 4.12 reveals that normal plant geometry recorded maximum net returns over rest of the two plant densities but brought about significant variation only over higher plant densities ha⁻¹ during both the years of study. Both the lower densities were at par with each other during the period of study. On the basis of pooled analysis normal plant density produced Rs 24292 ha⁻¹ which was Rs 355 and 4748 ha⁻¹ higher over medium and higher plant densities.

Fertility levels : An examination of data presented in Table 4.12 reveals that application of fertility levels significantly increased the net returns during both the years of investigation and on pooled basis. Application of 100% RDF recorded significantly higher net returns over 50 and 75% RDF. On pooled analysis increases with 100% RDF (Rs. 24875 ha⁻¹) registering of the order of 37.32 and 13.76 per cent, respectively over 50 and 75% RDF. However, data further reported that variation between 100 and 125% RDF failed to show any statistically variation with regards to net returns during both the years and on pooled results basis.

4.8.2 B:C ratio

Genotypes : A perusal of data depicted in Table 4.12 reveals that genotype CSV 15 recorded significantly higher B:C ratio over CSH 14 and SPV 1430 during both the years. On pooled basis, the per cent increase was to the magnitude of 7.64 and 12.98 per cent, respectively. While, genotype CSH 14 also observed significantly superior during second year of study and pooled analysis over SPV 1430.

Plant geometry : Further, normal plant geometry recorded significantly higher B:C ratio over higher plant densities during both the years of study. The corresponding increases were to the magnitude of 26.61, 31.22 and 28.94 per cent, respectively during 2003, 2004 and on pooled basis. However, variation between normal and medium plant geometries indicated statistically at par to each other during both the years and on pooled basis.

Fertility levels : A reference to data depicted in Table 4.12 shows that application of fertility levels significantly improved the B:C ratio upto 100% RDF during both the years of experimentation and on pooled basis. Application of 100% RDF recorded significantly higher B:C ratio over 50 and 75% RDF and registering to increases of the order of 24.48 and 4.70 per cent on pooled basis, respectively. However, further variation between 100 and 125% RDF was not seen statistically in B:C ratio during both the years and on pooled basis.

5. DISCUSSION

During course of presenting the results of field experiment entitled “Effect of plant geometry and fertility levels on productivity of various elite sorghum [*Sorghum bicolor* (L.) Moench] genotypes” in the preceding chapter, many significant variation in the criteria used for treatment evaluation were observed due to the effect of different treatments. In the ensuing pages an attempt has been made to discuss the variation found significant or having uniform trends and reconcile them into some tangible concept in order to explain the treatment differences for various parameters. Whenever, felt necessary experimental findings or observations of the other workers have been cited to support the results of the present experiment.

5.1 EFFECT OF CROP SEASON

The results indicate that between the years of investigation, the productivity of sorghum in terms of grain, fodder and biological yield were higher by 3.97, 2.48 and 2.82 per cent during the year 2004 over first year of experimentation.

It is an established fact that plants can realize their genetic potential under certain range of environmental factors i.e. weather conditions to which plants are exposed during their life cycle as well as internal environment i.e. availability of metabolites and nutrients. Despite the fact that crop was grown under identical management conditions and input levels, the observed variation in productivity of sorghum between the years seems to be due to variation in weather conditions which prevailing during various stages of crop growth. The profound influence of environmental factors on crop productivity is well established (Ulrich, 1992). Mavi and Tupper (2005) stated that plant can realize its genetic potential or complete its genetically programmed phasic development under certain range of environmental factors. While Mistry and Patel (1977) opined that weather is principal input parameter which brings year to year variation in crop productivity despite consistency of other input parameters and practices of crop husbandry.

The mean weakly weather parameters recorded during the crop growth period showed marked variation in amount and distribution of rainfall, sunshine hours, relative humidity and temperature (maximum and minimum) between the years (Appendix-I), while difference in other parameters was marginal. During the first year

of experimentation (Year 2003) the total rainfall received during rainy season was 465.9 mm. But in the year 2004, the total rainfall received during growing season was comparatively higher (569.6 mm) which was well distributed across various stages of plant growth. While, comparatively higher quantum of rainfall with proper distribution during 2004 seems to have provided congenial conditions (both above and below ground) for proper growth and development of sorghum plants. Even distribution of rains at critical crop growth stages coupled with availability of greater sunshine hours during the year, 2004, made it possible for the crop plants to accumulate higher photosynthates and better growth which is well evident from increased growth parameters like plant height as well as overall growth of the crop in terms of biomass accumulation at successive stages of crop growth. It is an established fact that adequate supply of metabolites and nutrients is pre requisites for proper growth and development of yield components, the adequate supply of these inputs during the year 2004 ultimately reflected in improvement of each yield component. Since grain yield is artifact of several yield components, the marked increase in yield components during 2004 manifested in realization of higher grain yield by 4.00 per cent over that recorded during 2003.

The increased fodder yield during 2004 compared to 2003 year of study seems to be on account of better growth of the crop as evident from increase in morphological parameters alongwith dry matter accumulation by the plants.

Since, biological yield is sum of grain and fodder yield, increase in both of these led to higher biological yield realized during 2004 compared to 2003.

5.2 EFFECT OF GENOTYPES

5.2.1 Growth characters

The sorghum genotypes differed significantly with respect to plant height and dry matter accumulation per plant where in CSV 15 proved superior over CSH 14 at 30 and 90 DAS and superior over SPV 1430 and CSH 14 at 90 DAS and at harvest with regard to plant height (Table 4.2). The variation in plant height of the genotypes might be related to inherent differences and high vigour. The differential behaviour of these genotypes could also be explained solely by the variation in their genetic make up (Muthiah and Ramanathan, 1983 and Dixit *et al.*, 2005).

A reference to data presented in Table 4.3 revealed that the genotype CSV 15 produced greater dry matter accumulation than SPV 1430 and CSH 14 at various

growth stages. Similarly, SPV 1430 was also superior to CSH 14. Dry matter production efficiency of genotypes determines its potential to produce economic yield (Curtis *et al.*, 1969). The differential behaviour of these genotypes in respect to growth parameters could also be explained solely by the variation in their genetic make up (Muthia and Ramanathan, 1983).

5.2.2 Yield attributes and yield

It was observed that CSH 14 produced significantly higher weight of panicle, grain weight of panicle, test weight and number of grains per panicle with concomitant increase in productivity of crop established in terms of grain and fodder yield ha^{-1} . These results corroborate with findings of (Mahakulkar *et al.*, 1992; Khatik *et al.*, 1999; Gupta and Mali, 1998; Singh and Sumeriya, 2004 and Dixit *et al.*, 2005). The higher grain yield and fodder yield registered by CSH 14 and CSV 15 over SPV 1430 appear to be a resultant of remarkable improvement in different yield components, which was brought about due to adoption of genotypes. It was further confirmed by the fact that seed yield was found strongly correlated with different yield components (Table 5.1). Seed yield, in turn, was found strongly correlated with the length of panicle, weight of panicle, grain weight of panicle, number of grains per panicle and test weight. Respective correlation coefficients were 0.661**, 0.926**, 0.950**, 0.897**, 0.39**. Every unit increase in these parameters *viz.* length of panicle, weight of panicle, grain weight of panicle and test weight increased seed yield of sorghum by 2.18, 0.93, 1.06, 0.04 and 2.71. such close association ship of grain yield with different yield components were also observed by Gupta (1997), Bishnoi (2002) and Kushwaha and Singh (2006).

5.2.3 Nutrient content and uptake

The nutrient (N and P) concentration is grain and fodder at harvest significantly influenced with genotypes (Table 4.6, 4.7 and 4.8). The improvement in nutrient status of plant under genotypes might be due to their genetic make up. It is generally believed that in the plant extracted nutrients are used for maintaining their critical concentration that can be used for plant growth or development structures. Thus, the greater availability of nutrient with CSH 14 seems to have critical concentration of cellular level and fulfilled their requirements for profuse plant growth and their efficient translocation towards sink component. The results are in

close conformity with the findings of Gupta (1997), Bishnoi (2002) and Dixit *et al.* (2005). Nutrients (N and P) uptake increased with genotypes (Table 4.7 and 4.8). As the uptake is a product of the yield and nutrient content, considerable increase in either of components may increase the uptake. The uptake of nutrients is mainly governed by the variation in grain and fodder yield and nutrient content. Genotypic variation in uptake by grain, fodder and total uptake of nitrogen and phosphorus by crop was significantly affected due to genotypes. However, comparing different genotypes for N and P nutrients, genotype CSH 14 recorded highest N and P uptake by grain, while, CSV 15 obtained highest N and P uptake in fodder and total uptake by the crop. Whereas, lowest uptake in grain, fodder and total uptake by crop was observed with genotype SPV 1430. Genetic variability in sorghum with respect to plant nutrients uptake of N and P were also observed by Trivedi *et al.* (1996), Dixit *et al.* (2005) and Sumeriya *et al.* (2005).

5.2.4 Available N, P and K status of soil

The status of available nitrogen and phosphorus in soil after harvesting of sorghum was lower than the initial status of soil under all the treatments due to the fact that sorghum crop is a heavy feeder of nitrogen and phosphorus.

5.3 EFFECT OF PLANT GEOMETRY (PLANT DENSITY)

5.3.1 Growth characters

The crop sown at plant geometry of 45 x 15, 45 x 10 and 30 x 10 cm (150,000, 220,000 and 330,000 plants per hectare) significant effect on different growth attributes *viz.*, plant population ha^{-1} , plant height and dry matter production plant^{-1} at successive growth stages and days to 50% bloom and maturity (Table 4.1 to 4.4). The results showed that reduction in geometry from 45 x 15 cm to 45 x 10 and 30 x 10 cm increased significantly number of plants ha^{-1} at final thinning and at harvest (Table 4.1). Further, the population densities were maintained, by and large, as per treatment and difference between actual population maintained and respective population density treatment was marginal. The close geometry (30 x 10 cm) recorded the higher number of plants ha^{-1} (330,000 plants ha^{-1}) and with increase in geometry (45 x 15 cm) the density reduced to 150,000 plants ha^{-1} . The said differences in plant population were expected as planting geometry govern the allocation of space to individual plants and its shape. Hence reduction in area plant^{-1} through decreasing

inter and intra row spacing resulted in accommodating higher plants per unit area. The results are in agreement with those of Poonia (1997), Bishnoi (2002) and Raskar *et al.* (2006).

Increase in plant height at normal plant population (150,000 plants) appears quite logical to infer that reduction in plant geometry increased number of plants ha^{-1} , resulting into reduction in availability of sunlight throughout thick crop canopy as a result of mutual shading. Similar results were reported by Poonia (1997), Gupta and Mali (1998) and Bishnoi (2002).

With the increase in plant density from 150,000 to 220,000 and 330,000 plants ha^{-1} there was significant reduction in dry matter accumulation per plant at 30, 60 and 90 DAS and at harvest. The days to 50% flowering and maturity were not significantly influenced by crop geometry (Table 4.4). In general, improvement in dry matter accumulation per plant under 150,000 plants ha^{-1} (45 x 15 cm plant geometry) could be ascribed to availability of more land area per plant, which implies higher growth inputs (Sunlight, nutrients, moisture etc.) to individual plant with least competition as compared to plants under narrow row spacing (30 x 10 cm).

The better availability of inputs under wider geometry (45 x 15 cm) might have helped plants to grow profusely, which in turn resulted in rapid initiation of leaves and their expansion, thereby giving higher LAI, ultimately resulting in higher rate of photosynthesis. Besides this, reduction in number of plants per unit area under wider geometry (45 x 15 cm) might have also provided favourable environment for root development below ground. This might have led to adequate supply of nutrients / metabolites from root to shoot, resulting in higher biomass accumulation per plant. Thus, favourable environment above and below ground under 45 x 15 cm geometry seems to have resulted in better performance of individual plants in terms of plant growth. The results are in agreement with those of Poonia (1997), Gupta and Mali (1998) and Kaushik and Shaktawat (2005).

5.3.2 Yield attributes and yield

Significant reduction in yield attributes like panicle length, weight of panicle, grain weight per panicle, test weight, number of grains per panicle and grain yield (q ha^{-1}) was noted when plant population raised from 150,000 to 330,000 plants (Table 4.4 and 4.5) where as, fodder was significantly increased upto 330,000 plants ha^{-1} compared to wider spacing. Biological yield recorded significantly higher at 220,000

plants ha⁻¹ over 330,000 plants and 150,000 plants ha⁻¹. The harvest index was significantly higher with normal plant density i.e. 150,000 plants ha⁻¹. The marked improvement in length of panicle, weight of panicle, grain weight of panicle, test weight, number of grains per panicle and grain yield (q ha⁻¹) under wider row spacing of 150,000 plants ha⁻¹ appears to be on account of vigorous growth of individual plant as reflected by total dry matter accumulation per plant. It is well established fact that in crops, availability of assimilates (source) and storage organ (sink) exert an important regulation function on the complex process of yield formation. Further, proper development of roots and nutrient status of plant ascribe to the view that they helped the plant to produce more number of grains and thereafter their development. There exist positive relationship between test weight and number of grains per panicle (0.821**). The results obtained by Poonia (1997), Gupta and Mali (1998), Kaushik (2000) and Bishnoi (2002) were in close confirmity. The increased productivity of individual plant under 150,000 plants ha⁻¹ (45 x 15 cm plant geometry) seems to be the resultant of improvement in each yield components of the crop.

In contrast to results obtained on yield attributes and grain, fodder and biological yields of sorghum under higher plant densities compared to lower plant density. Further, increased number of plants per unit area attributed to increased fodder and biological yield. The biological yield of crop is a function of grain and fodder yield. Thus, it can be concluded that significantly improvement in production on unit area basis at narrow row spacing or higher plant density is a function of increased fodder yield per unit area rather than a case of increased yield components per plant. The results of the present investigation corroborates findings of several researchers viz., Bishnoi (2002), Kaushik and Shaktawat (2005) and Raskar *et al.* (2006).

5.3.3 Nutrient content and uptake

It is well established fact that uniform distribution of plants over entire land surface with the adoption of appropriate spatial arrangement facilities efficient utilization of available growth factors both above and below ground surface for plant growth and development. Hence, overall improvement in plant growth at the crop geometry 45 x 15 cm seems to be resultant of higher availability and better utilization of plant nutrients due to uniform distribution and greater proliferation of plant roots throughout the soil profile enabling the plants to absorb nutrients from large soil mass

as well as from deeper soil layer. It is quite clear from the fact that the contents of N and P at harvest were maximum at this crop geometry (Table 4.6). The nutrient uptake was significantly more in grain at 45 x 15 cm and in fodder was higher at 45 x 10 and 30 x 10 cm crop geometry. This view is in concurrence with the findings of Mixon (1969) and Monteith (1972) who reported higher nutrient absorption due to greater root development. Thus, beneficial effect of this crop geometry to certain extent could be ascribed to its effectiveness to modify nutritional environment of plants as evident from higher concentration. Greater availability of N and P in the present study as evident by increased cellular concentration of these nutrients might have promoted higher growth of leaves as a result of enhance cell division and enlargement. Since, N and P are considered vital for the synthesis for protein and other metabolites, thus resulting in higher over all plant growth and development. Similar results were also reported by Bishnoi (2002) and Kaushik and Shaktawat (2005).

5.3.4 Net returns and B:C ratio

The results reveals that net returns and B:C ratio significantly increased under 45 x 15 cm (150,000 plants ha⁻¹) crop geometry compared to 30 x 10 cm (Table 4.11). It is obvious because seed yield increased with decrease in plant population and hence also increase in the net returns and B:C ratio. Similar observation were Made by Bishnoi *et al.* (2003) and Thakur *et al.* (2006).

5.4 EFFECT OF FERTILITY LEVELS

5.4.1 Growth characters

Application of increasing levels of nitrogen and phosphorus from 50 to 100% significantly improved various growth characters *viz.*, plant height, dry matter accumulation and days to 50% flowering reduced significantly, however, significant response in case of plant height at 30, 60, 90 DAS and at harvest was upto 100% RDF (Table 4.2). Significant response in case of dry matter accumulation at 60 and at harvest was upto 125% RDF (Table 4.3).

In general, overall improvement in growth of sorghum plants under the influence of increasing rates of fertility levels could be ascribed due to the potential role of N and P fertilizer in modifying soil and plant environment conducive for better development of both morphological and biochemical components of the growth. The role of nitrogen in synthesis of protein, chlorophyll and other organic compounds of

physiological importance is well established. Besides these, it has been widely documented that alike environmental factors, mineral nutrition particularly nitrogen plays an important regulative functional role in plant system through synthesis and translocation of growth hormones which generally act as stimuli for certain steps of growth and development (Beringer, 1980). Further, phosphorus fertilization improves various metabolic and physiological process, thus known as “energy currency” which is subsequently used for vegetative and reproductive growth through phosphorylation (Brady, 1996 and Tisdale *et al.*, 2002). In addition to this vital metabolic role, phosphorus is an important structural component of nucleic acid, phytin, phospholipids and enzymes. An adequate supply of phosphorus early in the life of a plant is important in laying down the primordia for its reproductive parts. It also increases the initiation of both first and second order rootlets and their development. The extensive root system helps in exploiting the maximum nutrients and water from soils (Tandon, 1987).

Under the present investigation preponderant effect of increasing rate of fertility levels on growth of the crops was due to the improvement in nutritional environment of the plants. This is very well evince from estimates of nutrient status of plants which showed that N application not only increased its concentration but also had synergistic effect on other indispensable nutrients like P (Table 4.8). Similarly, greater uptake of N and P by the crop at harvest suggests their greater availability right from vegetative stage as most of the nutrients at later stage (reproductive) are being translocated from vegetative parts. Thus, this assumption is well justified that higher nutrient status of plants under fertilizer application is due to their greater availability in soil environment as well as their better extraction by roots and thereafter, translocation within plant system. Superiority of fertility levels appears to have resulted on account of improved crop growth and better productivity favoured by improved nitrogen and phosphorus nutrition. The improvement in nutritional status of plants might have resulted in greater synthesis of amino acids and protein and other growth promoting substances which seems to have enhanced the meristematic activity and increased cell division and enlargement and their elongation resulting in higher plant height (Table 4.2).

The improvement in morphological as well as photosynthetic parameters (LAI and chlorophyll content) might have resulted in better interception and utilization of radiant energy leading towards higher photosynthesis and finally more accumulation

of dry matter of individual plants. Thus experimental evidences on higher biomass accumulation clearly establish potential role of fertilizer in exploiting favourable environment towards formation of higher photosynthates by the virtue of modifying most important photosynthetic components. The correlation studies also substantiated positive inter relationship between dry matter per plant at 90 DAS with plant height at 90 DAS (0.822**) and final dry matter per plant with plant height (0.723**). Further regression studies indicated strong dependence of dry matter per plant on aforesaid parameters as each unit increase in these increased dry matter by 0.471 g plant⁻¹ respectively (Table 5.1). The results of present investigation are in close conformity with findings of several researcher (Meghwanshi, 1992; Dashora, 1998; Dixit *et al.*, 2005; Kaushik and Shaktawat, 2005 and Singh *et al.*, 2005). Carvalho *et al.* (1982) reported that improvement in dry matter production under adequate N application was due to higher synthesis of chlorophyll by virtue of greater protein formation under its influences.

The phenological studies showed that fertilizer (N and P) application significantly reduced days required by plants to attain 50% flowering (Table 4.3). The observed crop behaviour under fertilizer application could be attributed to higher concentration and uptake of nutrients. This might have accelerated protein synthesis and earlier flower primordial development ultimately resulting in earlier flowering (Basavaraju and Bommegowda, 1982; Poonia, 1997; Patidar, 1999 and Dixit *et al.*, 2005).

5.4.2 Yield attributes and yield

Increasing rates of fertilizer application from 50 to 100% RDF significantly improved yield attributes, namely length of panicle, weight per panicle, grain weight per panicle, grains per panicle and 1000 grain weight with concomitant increase in grain yield. Further, increase in fertility levels to 125% RDF though maximized grain yield but failed to record significant superiority over 100% RDF in these respects. Fodder and biological yield recorded significantly upto 125% RDF (Table 4.5).

In the preceding section, it was well emphasized that increasing rates of fertilizer, markedly improved over all growth of the crop in terms of dry matter production per plant by virtue of its impact on morphological and photosynthetic components alongwith accumulation of nutrients. This suggests greater availability of nutrients and metabolites for growth and development of reproductive structure,

which ultimately led to realization of higher productivity of individual plants. One of the other probable reasons could be ascribed to earlier flowering, which might have provided greater duration for reproductive growth. The increased availability of nutrients and photosynthates might have enhanced number of flowers and their fertilization resulting in higher number of grains per panicle. Further, in most of cereals, greater assimilating surface at reproductive development results in better grain formation because adequate production of metabolites and their translocation towards grain as evident from improvement in nutrient concentration and their uptake (Table 4.6 to 4.8). This might have resulted in increased weight of individual grain expressed in terms of test weight. Since the grain weight per panicle is dependent on number of grains per panicle and weight of individual grain, the significant improvement in grain weight per panicle under fertility levels could be ascribed to improvement in both these parameters. The results of present investigation are in close conformity with findings of Jadhav (1994), Singh *et al.* (1996), Das *et al.* (2000), Kaushik (2000), Bishnoi (2002) and Singh and Sumeriya (2006).

Significant improvement in production of crop upto 100% RDF could be ascribed due to profound influence of N and P fertilization on vegetative and reproductive growth of the crop due to increase in nutrient content and uptake as well as production of photosynthates, and their translocation towards the yield formation. It is well established fact that crop yield is dependent on several components. The correlation studies also indicated positive inter relationship between grain yield and yield components *viz.*, length of panicle (0.661**), weight per panicle (0.926**), grain weight per panicle (0.950**), number of grains per panicle (0.897**) and test weight (0.939**). The regression studies revealed that unit increase in aforesaid characters increased the yield by 2.184, 0.90, 1.062, 0.040 and 2.711 q ha⁻¹, respectively.

The significant increases in fodder yield with increase fertility levels could be attributed to conducive effect on root and shoot growth of the plant which in term has accrued from increased plant height and dry matter accumulation. The correlation studies also substantiate significant positive relationship between fodder yield and plant height ($r=0.490^{**}$) as well as dry matter accumulation at harvest ($r=0.107$). The profound influence of fertilizers on biological yield seems to be on account of its influence on vegetative and reproductive aspects of crop growth. The results of present investigation are in close agreement with the findings of Tomar and Raghu

(1993), Jadhav (1994), Patidar (1999), Bishnoi (2002), Dixit *et al.* (2005), Kushwaha and Thakur (2006) and Singh and Sumeriya (2006).

5.4.3 Nutrient content and uptake

The estimation of nutrient concentration revealed marked improvement in nitrogen and phosphorus status in plants in grain and fodder at harvest with application of N and P fertilizers. The marked improvement in N content of vegetative parts seems to be on account of its greater availability in soil environment and translocation in plant system. Further, it has been reported that shoot and root growth mutually inherent with each other. Thus improvement in photosynthetic efficiency of plants as evidence from higher dry matter production by above ground parts might have supplied adequate metabolites for root growth and its functional activity. This might have helped in greater extraction of other nutrients like P resulting in improvement in their status. Increased in nutrients concentrations in grain with fertilizer application seems due to greater mobilization of nutrients from vegetative parts to grain. The total uptake of N and P by sorghum was increased significantly due to fertilizer application. The maximum uptake of N (131.45 kg ha⁻¹) and P (40.80 kg ha⁻¹) at harvest recorded with application of 100% RDF. It is an established fact that accumulation of nutrients is dependent on their concentration at cellular level and dry matter production. Thus, impact of N and P fertilizer on both there ultimately led to higher accumulation of nutrients by plant parts alongwith total uptake by the crop. Further cause and effect analysis also validated strong dependence of nutrients uptake on total dry matter production and each unit increase in dry matter production increased uptake of N and P by 0.30 and 0.2764 kg h⁻¹, respectively. The protein content of sorghum grain was significantly increased with an increase in the levels of fertility. Since the protein content is computed from the nitrogen content of the grain which has been enhanced under the above stated treatments because of increased availability of soil nitrogen. An increase in the protein content as a consequence of N and P fertilization is in agreement with the findings of Gill *et al.* (1988), Poonia (1997), Patidar (1999), Das *et al.* (2000), Kaushik (2000), Jat *et al.* (2003), Sumeriya *et al.* (2005) and Dixit *et al.* (2005).

5.4.4 Available N, P and K status of soil

The status of availability of N in the soil after harvesting of sorghum was lower than the initial status of the soil under all the treatment due to the fact that sorghum crop is a heavy feeder of N. At higher doses of nitrogen and phosphorus, the crop growth was also better than their lower doses. So naturally more uptake of nitrogen took place under these treatments. However, the available status of phosphorus and potassium in soil at harvest was observed with increasing fertility levels might be due to build up of nutrients in soil as a result of addition of N and P. Besides, on addition of fertilizer P to the soils, there might be some sort of triggering action on native soil P resulting in increased availability. Vaidya and Gabhane (1998) and Patil and Varade (1998) also reported increase in nutrient availability after harvest of sorghum with increasing rate of fertilizer application.

5.4.5 Net returns and B:C ratio

The increasing levels of fertility increased the net returns and B:C ratio (Table 4.12) upto 100% RDF, however variation between 100% was found at par with 125% RDF. It is obvious because seed yield increased with the increase in the fertility levels in proportion to cost of cultivation and B:C ratio and hence the net returns and B:C ratio. Similar observation were also made by Jat (1999), Kaushik (2000), Patidar (1999) and Singh and Sumariya (2006).

6. SUMMARY

The results of field experiment entitled “Effect of plant geometry and fertility levels on productivity of various elite sorghum [*Sorghum bicolor* (L.) Moench] genotypes” conducted at the Instructional Farm, Rajasthan College of Agriculture, Udaipur during *kharif* 2003 and 2004, presented and discussed in the preceding chapters are summarized as under :

6.1 EFFECT OF GENOTYPES

Growth parameters

- Plant population at final thinning as well as at harvest was not affected due to different genotypes.
- Maximum plant height of 48.60, 179.95, 232.34 and 235.91 cm at 30, 60 and 90 DAS and at harvest was observed by sowing the genotype CSV 15 significantly superior over SPV 1430 and CSH 14 except SPV 1430 only at 30 DAS significantly which was at par during both the years.
- Further, genotype SPV 1430 obtained plant height of 47.76, 209.64 and 210.63 cm at 30 and 90 DAS and at harvest respectively, proved statistically superior over CSH 14.
- Dry matter accumulation per plant at 30, 60 and 90 DAS and at harvest was significantly affected due to various cultivars, among the cultivars, CSV 15 recorded significantly higher dry matter accumulation over SPV 1430 and CSH 14 at all the stages of crop growth i.e. 30, 60, 90 DAS and at harvest.
- CSH 14 and SPV 1430 took significantly lesser number of days to 50 per cent flowering and maturity over CSV 15 during either years of experimentation.
- Genotype CSV 15 obtained significantly higher panicle length over SPV 1430 and CSH 14 while, genotype CHS 14 observed significantly higher panicle weight, grain weight per panicle, number of grains per panicle and test weight over CSV 15 and SPV 1430. The per cent increases with CSH 14 were of the order of 3.08 & 5.73, 5.61 & 10.05, 3.94 & 9.89 and 17.16 & 19.85 per cent, respectively over CSV 15 and SPV 1430.
- Genotypes CSH 14 (41.37 q ha⁻¹) produced significantly higher grain yield over CSV 15 and SPV 1430 and the increases were by 21.60 and 36.62 per cent

respectively over CSV 15 and SPV 1430. Further, CSV 15 reported 12.35 per cent higher grain yield over SPV 1430 (30.28 q ha⁻¹).

- Fodder and biological yields were significantly enhanced with growing CSV 15 (133.49 and 167.52 q ha⁻¹) which was found 9.08 and 32.59, 9.73 and 17.92 per cent higher over SPV 1430 and CSH 14, respectively. Where as, CSH 14 brought about significantly higher harvest index (29.32) over CSV 15 and SPV 1430.
- Maximum nitrogen and phosphorus contents in grain and fodder of 1.72, 0.582, 0.3367 and 0.2017 per cent were noted with genotype CSH 14 which was found significant superior over CSV 15 and SPV 1430.
- Genotype CSH 14 indicated significantly higher nitrogen uptake in grain and total uptake by crop over CSV 15 and SPV 1430. While, nitrogen uptake by fodder recorded significantly with CSV 15 over SPV 1430 and CSH 14.
- Phosphorus uptake by grain, fodder and total uptake was influenced significantly due to genotype. CSH 14 noted significantly higher P uptake by grain, whereas, CSH 15 significantly enhanced P uptake by fodder and total uptake by crops over SPV 1430 and CSH 14.
- Test hybrid CSH 14 brought about significantly higher protein content and their yield to the magnitude of 23.51 & 25.23 and 50.80 & 71.78 per cent respectively over CSV 15 and SPV 1430.
- Test genotype SPV 1430 observed significantly higher N and P content of soil after harvest of sorghum crop compared to CSV 15 and CSH 14.
- Genoytpe CSV 15 recorded significantly higher net monetary returns (Rs 23935 ha⁻¹) and B : C ratio (2.96) over CSH 14 and SPV 1430 during both the years of experimentation. However, genotype CSH 14 too obtained signifincatly higher net returns and B : C ratio (Rs 22893 ha⁻¹ and 2.75) as compared with SPV 1430.

6.2 PLANT GEOMETRY/POPULATION/DENSITY

- Plant population at 20 DAS and at harvest was affected significantly due to different plant densities. Highest plant population obtained significantly with 30 x 10 cm plant geometry over 45 x 10 cm (2.20) and 45 x 15 cm (1.50).
- Maximum plant height of 175.69, 224.80 and 226.15 cm was recorded at 60 and 90 DAS and at harvest with normal plant population i.e. 1.50 lac plants ha⁻¹ and found statistically superior over 2.20 and 3.30 lac plants ha⁻¹.

- Dry matter accumulation at all the plant growth stages were significantly influenced due to plant geometry. Plant geometry 45 x 15 cm recorded 3.03, 41.09, 74.71 and 79.72 g plant⁻¹ of dry matter production at 30, 60 and 90 DAS and at harvest respectively. Which was found 3.06 & 7.07, 17.50 & 37.65, 26.52 & 65.43 and 25.05 & 63.39 per cent higher over 45 x 10 and 30 x 10 cm crop geometry. Plant geometry 45 x 10 cm also significantly recorded higher DMA per plant at all the growth stages over 30 x 10 cm crop geometry.
- The various plant geometries were not able to bring any significant difference on days to 50 per cent flowering and maturity.
- The wider crop geometry of 45 x 15 cm produced significantly higher panicle length, weight of panicle, grain weight of panicle, test weight and number of grains per panicle compared to narrow crop geometries of 45 x 10 cm and 30 x 10 cm, respectively.
- Crop geometry 45 x 15 cm recorded significantly higher grain yield (42.67 q ha⁻¹) and harvest index over 45 x 10 and 30 x 10 cm. the corresponding increases were 14.83 & 65.07 and 25.55 & 75.25 per cent, respectively. Plant geometry 45 x 10 also noted significant increase in grain yield and harvest index over 30 x 10 cm. With regards to dry fodder yield, 30 x 10 cm crop geometry produced significantly maximum fodder yield over 45 x 15 and 45 x 10 cm and registering 23.67 and 5.75 per cent higher, respectively. However, crop geometry 45 x 10 cm recorded significantly higher in biological yield over 45 x 15 and 30 x 10 cm. The corresponding increases were by 8.30 and 2.75 per cent, respectively.
- Lower plant population i.e. 1.50 lac plants ha⁻¹ observed significantly higher nitrogen and phosphorus content in grain and fodder at harvest over remaining both the population i.e. 2.20 and 3.30 lac plants ha⁻¹ along both the years of experimentation.
- Crop geometry 45 x 15 cm recorded significantly higher nitrogen uptake by grain, and total uptake by the crop over 45 x 10 and 30 x 10 cm. The corresponding increases were by 20.87 & 82.38 and 8.24 & 31.52. However, with regards to phosphorus, highest uptake in grain recorded significantly with 45 x 15 cm geometry which was 19.03 and 79.06 per cent higher over 45 x 10 and 30 x 10 cm, respectively. However, with respect to P uptake by fodder, plant geometry 30 x 10 cm obtained significantly higher over 45 x 15 and 45 x 10 cm and the magnitude of increases were by 15.50 and 2.34 per cent. Further, data revealed

that plant geometry 45 x 10 and noted significantly higher total P uptake by the crop. The corresponding increasing was 10.77 per cent over 30 x 10 cm.

- Protein content and protein yield were significantly influenced with 1.50 lac plants ha⁻¹ which was increased by 5.13 & 11.05 and 20.87 & 82.40 per cent respectively over 2.20 lac and 3.30 lac plants ha⁻¹. However, medium plant density also proved significantly superior in protein content and protein yield over higher plant density (3.30 lac plants ha⁻¹). The corresponding increases were 5.64 and 50.90 per cent.
- Significantly higher N, P and K content of soil after harvest of sorghum crop were observed with plant density 1.50 lac plants ha⁻¹ over 2.20 and 3.30 lac plants ha⁻¹ during both the years of studies.
- Plant density of 1.50 lac plants ha⁻¹ observed significantly higher in net returns (Rs 24292 ha⁻¹) and B : C ratio (3.03) which was Rs 355 and Rs 4748 ha⁻¹ higher with 2.20 and 3.30 lac plants ha⁻¹. However, plant population 2.20 lac plants ha⁻¹ also recorded significantly higher net returns and B : C ratio of 3.30 lac plants ha⁻¹.

6.3 FERTILITY LEVELS

- Plant population at 20 DAS as well as at harvest was not affected significantly due to various fertility levels.
- Application of 100 % RDF (80 kg N + 40 kg P₂O₅ ha⁻¹) gave significantly higher plant height at 30, 60 and 90 DAS and at harvest over 50 % RDF. Higher and lower doses of this level i.e. 125 % RDF and 75 % RDF were found statistically at par to each other. The corresponding increases were by 7.50, 18.44, 13.65 and 13.82 per cent higher with 100 % RDF over 50 % RDF, respectively.
- Application of fertility levels significantly increases DMA plant⁻¹ upto 125 % RDF at 30, 60 and 90 DAS and at harvest. The corresponding increases were of the magnitude of 48.89, 13.18 & 5.35 per cent, at 30 DAS; 57.29, 22.11 & 7.74 per cent, at 60 DAS; 35.02, 6.41 & 2.70 per cent, at 90 DAS and 34.48, 13.88 and 4.81 per cent at harvest higher over 50, 75 and 100 per cent RDF, respectively. However, application of 100 % RDF also significantly recorded DMA plant⁻¹ at 30, 60 and 90 DAS and at harvest over 50 and 75 per cent RDF. The corresponding increases were by 41.33 & 7.43, 45.99 & 13.33, 31.48 & 3.62 and 28.31 & 8.66 per cent, respectively.

- Application of 100 % RDF gave significantly lesser number of days to 50 per cent flowering and days to maturity as compared with 50 and 75 per cent RDF.
- All the yield attributing characters *viz.*, length of panicle, weight and grain weight of panicle, test weight and number of grains panicle⁻¹ increased significantly with the increase in levels of fertility from 50 to 100 per cent RDF. The difference between 100 and 125 per cent RDF with respect to all the above yield attributing characters were found not significant. The per cent increases were by 10.53 & 4.94, 16.31 & 5.97, 18.55 & 7.23, 8.45 & 1.75 and 9.22 & 5.65 over 50 and 75 per cent RDF respectively in aforesaid yield attributing characters with the application of 100 % RDF.
- The grain yield of sorghum increased significantly with the increasing levels of applied N and P fertilizers from 50 to 100 per cent RDF. However, the difference between 100 and 125 per cent RDF was at par. The corresponding increases with 100 % RDF over 50 and 75 % RDF to the magnitude of 38.96 and 14.97 per cent, respectively.
- Fodder and biological yields increased significantly with the increasing levels of fertility from 50 to 125 % RDF. The increase in fodder and biological yields due to application of 125 % RDF were by 27.06, 14.24 & 5.85 and 29.86, 14.64 and 4.66 per cent over 50, 75 and 100 % RDF respectively.
- Harvest index of sorghum crop significantly increased with ever increasing in fertility levels from 50 to 100 % RDF.
- Application of NP fertilization upto 125 % RDF significantly increased the nitrogen and phosphorus content in grain and fodder at harvest of the crop during both the years of experimentation.
- Successive application of fertility levels upto 125% RDF significantly increased nitrogen and phosphorus uptake in grain and fodder at harvest and total uptake by crop. The per cent increases were of the magnitude of 54.52, 20.53 & 3.23, 57.83, 28.56 & 12.30 and 56.23, 24.57 & 7.77 per cent of N uptake by grain, fodder and total by the crop and 60.85, 24.00 & 4.04; 44.24, 22.95 & 9.25 and 49.34, 23.30 & 7.45 per cent in phosphorus uptake by grain, fodder and total by the crop over 50, 75 and 100 % RDF, respectively.
- The increasing levels of fertility upto 125 % RDF significantly increased the protein content and protein yield. The increases due to application of 75, 100 and

125 % RDF by 5.88, 7.57 & 9.83 and 28.20, 49.67 & 54.50 per cent, respectively over 50 % RDF.

- The available N, P and K contents of soil after harvest of sorghum crop was significantly increased due to increasing levels of fertility up to 125 %. The increases due to application of 75, 100 and 125 % RDF by 3.67, 6.80 and 8.37 per cent in nitrogen, 4.65, 8.08 and 10.29 per cent in phosphorus and 3.23, 4.20 and 5.11 per cent in potassium contents over 50 % RDF, respectively.
- Application of 100 % RDF gave significantly higher net return (Rs 24875 ha⁻¹) and B : C ratio (3.00) as compared to lower levels of fertility applied. The difference between 100 and 125 % RDF was found non-significant with regards to net returns and B : C ratio.

6.4 INTERACTION EFFECT OF GENOTYPES AND FERTILITY LEVELS

- The maximum plant height at 60 and 90 DAS and at harvest obtained under 125 % RDF with CSV 15 which was statistically at par with 100 % RDF with same genotype.
- The combined effect of genotypes and fertility levels significantly influenced DMA plant⁻¹ at 60 DAS and at harvest. The highest value of this parameter was obtained under 125 % RDF with CSV 15 closely followed by 100 % RDF with genotype CSV 15.
- Significantly higher grain yield was observed under genotype CSH 14 when fertilized with 100 % RDF, which was at par with 125 % RDF with CSH 14 in this respect.
- Significantly higher nitrogen content in grain and phosphorus content in fodder was obtained under CSH 14 when fertilized with 125 % RDF.
- The significantly higher nitrogen uptake in grain and total N uptake by crop was obtained under CSH 14 fertilized with 125 % RDF.
- The combined effect of genotypes and fertility levels significantly influenced P uptake in grain at harvest. The highest value was recorded under 125 % RDF with test genotype CSH 14.
- The highest protein content and protein yield was obtained under genotype CSH 14 fertilized with 125 % RDF.

6.5 INTERACTION EFFECT OF GENOTYPES AND PLANT GEOMETRY

- The significant higher phosphorus content (%) in fodder was obtained under 45 x 15 cm crop geometry with genotype CSH 14.
- The combined effect of genotypes and plant geometry significantly influenced N uptake in grain and total N uptake by the crop at harvest and the highest value was recorded at 45 x 15 cm with genotype CSH 14. Which was closely followed by 45 x 10 cm geometry with CSH 14.
- The highest phosphorus uptake by grain at harvest was observed with genotype CSH 14 alongwith crop geometry of 45 x 15 cm which was closely followed by same genotype under 45 x 10 cm crop geometry.
- The significantly higher protein yield was obtained under crop geometry 45 x 15 cm with CSH 14 which was closely followed by 45 x 10 cm alongwith CSH 14 and 45 x 15 cm crop geometry with CSV 15.

7. CONCLUSION

Sorghum genotype CSH 14 planted in plant geometry of 45 cm x 15 cm and fertilized with 80 kg N + 40 kg P₂O₅ ha⁻¹ yielded maximum grain whereas genotype CSV 15 in the crop geometry of 30 x 10 cm and fertilizer level of 100 kg N + 50 kg P₂O₅ ha⁻¹ can be a cost effective choice for fodder purpose in rainfed situations of zone IV a of Rajasthan.

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Table 4.1 : Effect of plant geometry, fertility levels and genotypes on plant population of sorghum

Treatments	Plant population ('000 plants ha ⁻¹)					
	20 DAS			At harvest		
	2003	2004	Pooled	2003	2004	Pooled
Genotypes						
CSV 15	244.62	243.33	243.98	232.62	232.33	232.47
SPV 1430	244.85	247.50	246.18	232.85	236.50	234.68
CSH 14	244.86	247.27	246.07	232.86	236.27	234.57
SEm±	2.18	2.27	1.58	2.11	2.07	1.48
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
Plant geometry						
45 x 15 cm	160.20	161.77	160.99	148.90	150.87	149.89
45 x 10 cm	232.61	233.23	232.92	220.61	222.23	221.42
30 x 10 cm	341.52	343.10	342.31	329.52	332.10	330.81
SEm±	2.18	2.27	1.58	2.11	2.07	1.48
CD (P = 0.05)	6.33	6.80	4.75	6.33	6.20	4.26
Fertility levels						
50 % RDF	244.54	244.78	244.66	232.54	233.78	233.16
75 % RDF	244.78	246.21	245.50	232.78	235.21	234.00
100 % RDF	244.87	246.59	245.73	232.87	235.59	234.23
125 % RDF	244.91	246.56	245.74	232.91	235.56	234.24
SEm±	1.88	1.83	1.36	1.83	1.73	1.26
CD (P = 0.05)	NS	NS	NS	NS	NS	NS

Table 4.2 : Effect of plant geometry, fertility levels and genotypes on plant height (cm) of sorghum

Treatments	Plant height (cm)											
	30 DAS			60 DAS			90 DAS			Harvest		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
Genotypes												
CSV 15	47.33	49.87	48.60	176.99	182.91	179.95	230.12	235.36	232.74	233.72	238.09	235.91
SPV 1430	47.08	48.44	47.76	166.30	169.77	168.04	208.91	210.36	209.64	209.75	211.51	210.63
CSH 14	41.57	42.58	42.07	160.96	165.73	163.35	194.89	197.90	196.39	197.71	198.61	198.16
SEm±	0.66	0.74	0.50	2.78	2.48	1.86	3.00	3.47	2.29	3.75	3.92	2.72
CD (P = 0.05)	1.99	2.23	1.43	8.34	7.43	5.37	9.00	10.40	6.61	11.23	11.76	7.81
Plant geometry												
45 x 15 cm	45.77	48.12	46.95	173.53	177.86	175.69	223.72	225.88	224.80	225.09	227.20	226.15
45 x 10 cm	45.22	46.81	46.01	168.46	173.48	170.97	213.87	214.98	214.42	216.68	217.25	216.96
30 x 10 cm	44.99	45.96	45.47	162.27	167.07	164.67	196.32	202.76	199.54	199.41	203.77	201.59
SEm±	0.66	0.74	0.50	2.78	2.48	1.86	3.00	3.47	2.29	3.75	3.92	2.71
CD (P = 0.05)	NS	NS	NS	8.34	7.43	5.37	9.00	10.40	6.61	11.23	11.76	7.81
Fertility levels												
50 % RDF	42.72	44.74	43.73	147.28	152.75	150.01	191.20	195.12	193.16	194.32	195.65	194.98
75 % RDF	45.69	47.06	46.38	171.67	176.10	173.64	212.38	217.48	214.93	215.91	216.41	216.16
100 % RDF	46.14	47.89	47.01	175.22	180.11	177.67	218.72	220.32	219.52	220.32	223.53	221.93
125 % RDF	46.75	48.16	47.45	178.66	182.26	180.46	222.92	225.25	224.08	224.37	228.69	226.53
SEm±	0.57	0.60	0.42	2.27	2.07	1.54	2.32	2.60	1.75	3.04	2.88	2.09
CD (P = 0.05)	1.63	1.71	1.17	6.43	5.88	4.31	6.68	7.36	4.91	8.62	8.15	5.87

Table 4.3 : Effect of plant geometry, fertility levels and genotypes on dry matter accumulation (DMA) of sorghum

Treatments	Dry matter accumulation (DMA g plant ⁻¹)											
	30 DAS			60 DAS			90 DAS			At harvest		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
Genotypes												
CSV 15	3.09	3.30	3.19	37.88	38.16	38.02	62.92	66.73	64.82	66.28	68.37	67.33
SPV 1430	2.97	3.12	3.05	34.58	33.87	34.22	56.54	60.41	58.48	62.97	62.00	62.48
CSH 14	2.48	2.64	2.56	32.41	34.92	33.66	55.28	55.96	55.62	61.09	63.81	62.45
SEm±	0.04	0.04	0.03	0.49	0.45	0.33	0.97	0.85	0.65	1.00	0.87	0.66
CD (P = 0.05)	0.13	0.13	0.09	1.47	1.35	0.96	2.91	2.55	1.86	2.99	2.60	1.90
Plant geometry												
45 x 15 cm	2.94	3.12	3.03	40.20	41.98	41.09	72.46	76.96	74.71	78.45	81.00	79.72
45 x 10 cm	2.85	3.02	2.94	35.05	34.89	34.97	58.01	60.08	59.05	63.53	63.97	63.75
30 x 10 cm	2.75	2.92	2.83	29.62	30.08	29.85	44.27	46.05	45.16	48.37	49.21	48.79
SEm±	0.04	0.04	0.03	0.49	0.45	0.33	0.97	0.85	0.65	1.00	0.87	0.66
CD (P = 0.05)	0.13	0.13	0.09	1.47	1.35	0.96	2.91	2.55	1.86	2.99	2.60	1.90
Fertility levels												
50 % RDF	2.21	2.28	2.25	26.55	26.54	26.55	45.59	51.11	48.35	52.48	54.15	53.31
75 % RDF	2.88	3.04	2.96	33.78	34.61	34.20	60.32	62.37	61.35	63.96	61.94	62.95
100 % RDF	3.06	3.30	3.18	38.57	38.95	38.76	63.03	64.12	63.57	67.41	69.38	68.40
125 % RDF	3.24	3.46	3.35	40.93	42.49	41.76	64.04	66.53	65.28	69.94	73.43	71.69
SEm±	0.04	0.05	0.03	0.40	0.41	0.29	1.06	0.98	0.72	1.11	0.91	0.72
CD (P = 0.05)	0.11	0.14	0.09	1.12	1.17	0.80	3.00	2.77	2.02	3.14	2.59	2.01

Table 4.4 : Effect of plant geometry, fertility levels and genotypes on days to 50% flowering and maturity of sorghum

Treatments	Days to					
	50% flowering			Maturity		
	2003	2004	Pooled	2003	2004	Pooled
Genotypes						
CSV 15	62.81	62.06	62.43	111.80	110.30	111.10
SPV 1430	61.58	62.03	61.81	92.60	92.30	92.40
CSH 14	57.50	58.44	57.97	96.50	98.70	97.60
SEm±	0.51	0.57	0.38	0.60	0.60	0.40
CD (P = 0.05)	1.53	1.72	1.11	1.70	1.90	1.20
Plant geometry						
45 x 15 cm	59.75	60.78	60.26	99.80	100.00	99.90
45 x 10 cm	60.81	60.86	60.83	100.30	100.20	100.25
30 x 10 cm	61.33	60.89	61.11	101.80	101.00	101.40
SEm±	0.51	0.57	0.38	0.60	0.60	0.40
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
Fertility levels						
50 % RDF	61.70	62.00	61.85	103.70	102.00	102.90
75 % RDF	60.63	60.44	60.54	100.60	100.40	100.50
100 % RDF	60.22	60.44	60.33	99.20	99.40	99.30
125 % RDF	59.96	60.48	60.22	99.00	98.50	98.70
SEm±	0.42	0.39	0.28	0.60	0.50	0.40
CD (P = 0.05)	1.18	1.10	0.80	1.60	1.40	1.10

Table 4.5 : Effect of plant geometry, fertility levels and genotypes on yield attributes of sorghum

Treatments	Yield attributes														
	Panicle length (cm)			Weight of panicle (g)			Grain weight of panicle (g)			Test weight (g)			No. of grains per panicle		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
Genotypes															
CSV 15	28.25	29.01	28.63	90.00	93.68	91.84	73.90	76.42	75.16	25.17	25.75	25.46	2841.11	2875.56	2858.33
SPV 1430	26.17	26.52	26.35	87.83	91.25	89.54	70.62	73.63	72.13	24.50	25.48	24.89	2687.63	2719.68	2703.65
CSH 14	25.59	26.18	25.89	93.64	95.70	94.67	78.39	80.37	79.38	29.47	30.19	29.83	2971.51	2970.33	2970.92
SEm±	0.40	0.36	0.27	1.06	1.16	0.78	1.01	0.97	0.70	0.36	0.33	0.24	52.00	54.40	37.63
CD (P = 0.05)	1.20	1.09	0.78	3.18	3.46	2.26	3.02	2.92	2.02	1.07	0.98	0.70	155.91	163.10	108.40
Plant geometry															
45 x 15 cm	29.59	29.96	29.78	97.65	103.09	100.37	80.18	84.64	82.41	29.08	29.85	29.47	2970.48	3048.16	3009.32
45 x 10 cm	26.49	27.09	26.79	91.34	94.11	92.73	75.00	77.28	76.14	26.46	27.31	26.89	2845.14	2849.07	2847.10
30 x 10 cm	23.93	24.66	24.30	82.47	83.43	82.95	67.72	68.50	68.11	23.59	24.07	23.83	2684.64	2668.33	2676.48
SEm±	0.40	0.36	0.27	1.06	1.16	0.78	1.01	0.97	0.70	0.36	0.33	0.24	52.00	54.40	37.63
CD (P = 0.05)	1.20	1.09	0.78	3.18	3.46	2.26	3.02	2.92	2.02	1.07	0.98	0.70	155.91	163.10	108.40
Fertility levels															
50 % RDF	24.88	25.45	25.16	80.99	84.68	82.83	65.92	68.43	67.18	24.98	25.43	25.21	2664.93	2716.13	2690.53
75 % RDF	26.12	26.88	26.50	89.56	92.26	90.91	73.17	75.37	74.27	26.43	27.30	26.87	2787.71	2774.99	2781.35
100 % RDF	27.60	28.01	27.81	94.60	98.08	96.34	78.21	81.08	79.64	27.01	27.67	27.34	2920.49	2956.59	2938.54
125 % RDF	28.09	28.60	28.34	96.80	99.16	97.98	79.90	82.35	81.12	27.11	27.90	27.50	2960.54	2973.04	2966.79
SEm±	0.35	0.33	0.24	1.16	1.29	0.86	0.96	1.08	0.72	0.32	0.36	0.24	44.11	55.62	35.49
CD (P = 0.05)	0.99	0.92	0.67	3.28	3.65	2.42	2.73	3.06	2.02	0.92	1.02	0.68	125.07	157.69	99.50

Table 4.6 : Effect of plant geometry, fertility levels and genotypes on yield of sorghum

Treatments	Yields (q ha ⁻¹)											
	Grain			Fodder			Biological			Harvest index (%)		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
Genotypes												
CSV 15	33.33	34.71	34.02	131.98	135.01	133.49	165.30	169.73	167.52	20.30	20.60	20.45
SPV 1430	29.95	30.61	30.28	121.58	123.19	122.38	151.53	153.80	152.66	19.81	19.90	19.86
CSH 14	40.33	42.42	41.37	98.65	102.72	100.68	138.98	145.14	142.06	29.25	29.39	29.32
SEm±	0.62	0.52	0.40	2.11	2.04	1.47	2.21	1.92	1.46	0.47	0.53	0.35
CD (P = 0.05)	1.85	1.56	1.16	6.31	6.12	4.22	6.63	5.75	4.21	1.40	1.60	1.02
Plant geometry												
45 x 15 cm	41.43	43.92	42.67	103.93	105.44	104.68	145.35	149.36	147.35	28.96	29.83	29.39
45 x 10 cm	36.37	37.94	37.16	120.15	124.69	122.42	156.53	162.63	159.58	23.46	23.47	23.47
30 x 10 cm	25.80	25.89	25.85	128.13	130.79	129.46	153.93	156.68	155.31	16.94	16.60	16.77
SEm±	0.62	0.52	0.40	2.11	2.04	1.47	2.21	1.92	1.46	0.47	0.53	0.35
CD (P = 0.05)	1.85	1.56	1.16	6.31	6.12	4.22	6.63	5.75	4.21	1.40	1.60	1.02
Fertility levels												
50 % RDF	27.96	28.41	28.18	102.33	105.12	103.73	130.29	133.53	131.91	21.96	21.72	21.84
75 % RDF	33.33	34.80	34.06	113.79	116.96	115.37	147.11	151.75	149.43	23.17	23.37	23.27
100 % RDF	38.31	40.01	39.16	122.86	126.18	124.52	161.17	166.19	163.68	24.19	24.43	24.31
125 % RDF	38.54	40.45	39.50	130.64	132.97	131.80	169.18	173.42	171.30	23.16	23.68	23.42
SEm±	0.50	0.54	0.37	2.34	2.52	1.72	2.39	2.61	1.77	0.50	0.45	0.34
CD (P = 0.05)	1.43	1.53	1.04	6.63	7.15	4.82	6.79	7.41	4.97	1.43	1.27	0.94

Table 4.7 : Effect of plant geometry, fertility levels and genotypes on nitrogen and phosphorus content at harvest of sorghum

Treatments	Nitrogen content (%)						Phosphorus content (%)					
	Grain			Fodder			Grain			Fodder		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
Genotypes												
CSV 15	1.38	1.41	1.39	0.465	0.463	0.464	0.3233	0.3133	0.3183	0.1933	0.2000	0.1967
SPV 1430	1.37	1.38	1.38	0.455	0.450	0.453	0.3233	0.2967	0.3100	0.1900	0.1900	0.1900
CSH 14	1.70	1.75	1.72	0.528	0.527	0.528	0.3367	0.3367	0.3367	0.1967	0.2067	0.2017
SEm±	0.011	0.008	0.007	0.004	0.003	0.003	0.002	0.002	0.001	0.001	0.001	0.001
CD (P = 0.05)	0.034	0.023	0.020	0.011	0.010	0.007	0.006	0.006	0.004	0.003	0.004	0.003
Plant geometry												
45 x 15 cm	1.56	1.59	1.58	0.530	0.530	0.530	0.3400	0.3300	0.3350	0.2000	0.2067	0.2034
45 x 10 cm	1.48	1.51	1.50	0.483	0.463	0.473	0.3267	0.3167	0.3217	0.1933	0.2000	0.1967
30 x 10 cm	1.41	1.43	1.42	0.430	0.447	0.439	0.3133	0.3000	0.3067	0.1867	0.1900	0.1884
SEm±	0.011	0.008	0.007	0.004	0.003	0.003	0.002	0.002	0.001	0.001	0.001	0.001
CD (P = 0.05)	0.034	0.023	0.020	0.011	0.010	0.007	0.006	0.006	0.004	0.003	0.004	0.003
Fertility levels												
50 % RDF	1.40	1.43	1.42	0.423	0.430	0.427	0.3033	0.2900	0.2967	0.1833	0.1833	0.1833
75 % RDF	1.48	1.51	1.50	0.473	0.467	0.470	0.3267	0.3133	0.3200	0.1900	0.1900	0.1900
100 % RDF	1.51	1.54	1.52	0.500	0.496	0.498	0.3367	0.3267	0.3317	0.1933	0.2033	0.1983
125 % RDF	1.54	1.57	1.55	0.533	0.520	0.527	0.3500	0.3367	0.3434	0.2033	0.2100	0.2067
SEm±	0.009	0.008	0.006	0.004	0.003	0.002	0.002	0.002	0.001	0.001	0.001	0.001
CD (P = 0.05)	0.025	0.024	0.017	0.010	0.009	0.007	0.007	0.005	0.004	0.004	0.004	0.003

Table 4.8 : Effect of plant geometry, fertility levels and genotypes on nitrogen uptake (kg ha⁻¹) by sorghum

Treatments	Nitrogen uptake (kg ha ⁻¹)								
	Grain			Fodder			Total N uptake		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
Genotypes									
CSV 15	46.50	49.50	48.00	61.17	61.92	61.55	107.68	111.42	109.55
SPV 1430	41.39	42.89	42.14	55.20	55.30	55.25	96.59	98.19	97.39
CSH 14	69.56	75.20	72.38	52.19	53.80	53.00	121.75	129.01	125.38
SEm±	1.05	0.78	0.65	1.11	1.18	0.81	1.45	1.10	0.91
CD (P = 0.05)	3.16	2.33	1.89	3.31	3.54	2.33	4.34	3.30	2.62
Plant geometry									
45 x 15 cm	65.70	71.12	68.41	55.32	55.45	55.39	121.02	126.58	123.80
45 x 10 cm	54.82	58.38	56.60	58.08	57.48	57.78	112.91	115.86	114.38
30 x 10 cm	36.93	38.08	37.51	55.15	58.09	56.62	92.08	96.17	94.13
SEm±	1.05	0.78	0.65	1.11	1.18	0.81	1.45	1.10	0.91
CD (P = 0.05)	3.16	2.33	1.89	NS	NS	NS	4.34	3.30	2.62
Fertility levels									
50 % RDF	39.83	41.58	40.70	42.58	44.29	43.44	82.41	85.41	84.14
75 % RDF	50.44	53.92	52.18	52.94	53.73	53.33	103.39	107.65	105.52
100 % RDF	58.99	62.85	60.92	60.23	61.88	61.05	119.22	124.73	121.97
125 % RDF	60.68	65.09	62.89	68.99	68.13	68.56	129.67	133.23	131.45
SEm±	0.70	0.87	0.56	1.22	1.31	0.90	1.41	1.61	1.07
CD (P = 0.05)	1.99	2.46	1.56	3.47	3.71	2.51	4.01	4.55	3.00

Table 4.9 : Effect of plant geometry, fertility levels and genotypes on phosphorus uptake (kg ha⁻¹) by sorghum

Treatments	Phosphorus uptake (kg ha ⁻¹)								
	Grain			Fodder			Total P uptake		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
Genotypes									
CSV 15	10.95	11.05	11.00	25.26	26.88	26.07	36.21	37.93	37.07
SPV 1430	9.63	9.33	9.48	22.89	23.78	23.33	32.52	33.11	32.82
CSH 14	13.85	14.51	14.18	19.58	21.03	20.31	33.43	35.55	34.49
SEm±	0.24	0.19	0.15	0.44	0.41	0.30	0.52	0.41	0.33
CD (P = 0.05)	0.72	0.57	0.44	1.33	1.24	0.87	1.57	1.23	0.96
Plant geometry									
45 x 15 cm	14.19	14.72	14.45	20.71	21.75	21.23	34.90	36.47	35.68
45 x 10 cm	12.02	12.27	12.14	23.16	24.76	23.96	35.18	37.03	36.10
30 x 10 cm	8.23	7.90	8.07	23.86	25.18	24.52	32.09	33.08	32.59
SEm±	0.24	0.19	0.15	0.44	0.41	0.30	0.52	0.41	0.33
CD (P = 0.05)	0.72	0.57	0.44	1.33	1.24	0.87	1.57	1.23	0.96
Fertility levels									
50 % RDF	8.53	8.42	8.48	18.53	19.13	18.83	27.07	27.56	27.32
75 % RDF	10.92	11.07	11.00	21.54	22.65	22.09	32.46	33.72	33.09
100 % RDF	12.99	13.23	13.11	24.00	25.73	24.86	36.99	38.96	37.97
125 % RDF	13.47	13.81	13.64	26.24	28.08	27.16	39.71	41.88	40.80
SEm±	0.18	0.19	0.13	0.50	0.53	0.36	0.53	0.57	0.39
CD (P = 0.05)	0.52	0.53	0.37	1.42	1.49	1.02	1.50	1.62	1.09

Table 4.10 : Effect of plant geometry, fertility levels and genotypes on protein content (%) and protein yield (kg ha⁻¹) of sorghum

Treatments	Protein content (%)			Protein yield (kg ha ⁻¹)		
	2003	2004	Pooled	2003	2004	Pooled
Genotypes						
CSV 15	8.62	8.81	8.72	290.66	309.35	300.00
SPV 1430	8.56	8.65	8.60	258.67	268.05	263.36
CSH 14	10.63	10.92	10.77	434.77	470.01	452.39
SEm±	0.07	0.05	0.04	6.59	4.85	4.09
CD (P = 0.05)	0.21	0.14	0.12	19.75	14.55	11.78
Plant geometry						
45 x 15 cm	9.75	9.95	9.85	410.63	444.52	427.58
45 x 10 cm	9.28	9.46	9.37	342.64	364.87	353.75
30 x 10 cm	8.79	8.96	8.87	230.83	238.02	234.42
SEm±	0.07	0.05	0.04	6.59	4.85	4.09
CD (P = 0.05)	0.21	0.14	0.12	19.75	14.55	11.78
Fertility levels						
50 % RDF	8.75	8.95	8.85	248.91	259.89	254.40
75 % RDF	9.27	9.46	9.37	315.28	337.00	326.14
100 % RDF	9.43	9.61	9.52	368.67	392.82	380.75
125 % RDF	9.62	9.81	9.72	379.26	406.83	393.05
SEm±	0.06	0.05	0.04	4.38	5.41	3.48
CD (P = 0.05)	0.16	0.15	0.11	12.42	15.35	9.76

Table 4.11 : Effect of plant geometry, fertility levels and genotypes on available nutrients in soil after harvest of sorghum

Treatments	Available nutrients (kg ha ⁻¹)								
	Nitrogen			Phosphorus			Potassium		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
Genotypes									
CSV 15	256.00	249.56	252.78	19.30	18.92	19.11	352.05	351.07	351.56
SPV 1430	256.95	251.70	254.33	19.97	19.41	19.69	352.46	353.58	353.02
CSH 14	246.79	238.23	242.51	18.85	18.27	18.56	347.91	344.85	346.38
SEm±	1.96	2.07	1.43	0.17	0.16	0.12	2.867	3.054	2.094
CD (P = 0.05)	5.88	6.21	4.11	0.50	0.49	0.34	NS	NS	NS
Plant geometry									
45 x 15 cm	270.85	262.67	266.76	20.02	20.12	20.07	359.24	358.50	358.87
45 x 10 cm	257.31	249.53	253.42	19.63	19.01	19.32	349.52	347.23	348.37
30 x 10 cm	231.58	227.29	229.44	18.47	17.46	17.97	343.65	343.77	343.71
SEm±	1.96	2.07	1.43	0.17	0.16	0.12	2.867	3.054	2.094
CD (P = 0.05)	5.88	6.21	4.11	0.50	0.49	0.34	8.594	9.155	6.033
Fertility levels									
50 % RDF	241.53	235.74	238.63	18.28	17.89	18.08	340.87	338.47	339.67
75 % RDF	249.86	244.92	247.39	19.24	18.59	18.92	351.92	349.36	350.64
100 % RDF	259.25	250.45	254.85	19.77	19.31	19.54	353.23	354.66	353.95
125 % RDF	262.34	254.87	258.61	20.21	19.67	19.94	357.20	356.85	357.02
SEm±	2.11	2.23	1.53	0.18	0.17	0.12	3.220	3.467	2.366
CD (P = 0.05)	5.98	6.32	4.30	0.50	0.49	0.35	9.131	9.831	6.633

Table 4.12 : Effect of plant geometry, fertility levels and genotypes on net returns and B : C ratio

Treatments	Net returns (Rs. ha ⁻¹)			B : C ratio		
	2003	2004	Pooled	2003	2004	Pooled
Genotypes						
CSV 15	23434	24436	23935	2.90	3.03	2.96
SPV 1430	20695	21196	20945	2.59	2.65	2.62
CSH 14	22167	23618	22893	2.66	2.83	2.75
SEm±	388	277	239	0.05	0.03	0.03
CD (P = 0.05)	1163	832	687	0.15	0.10	0.08
Plant geometry						
45 x 15 cm	23637	24947	24292	2.95	3.11	3.03
45 x 10 cm	23301	24574	23937	2.87	3.03	2.95
30 x 10 cm	19358	19729	19544	2.33	2.37	2.35
SEm±	388	277	239	0.05	0.03	0.03
CD (P = 0.05)	1163	832	687	0.15	0.10	0.08
Fertility levels						
50 % RDF	17838	18391	18115	2.37	2.45	2.41
75 % RDF	21297	22356	21827	2.69	2.83	2.76
100 % RDF	24285	25464	24875	2.93	3.07	3.00
125 % RDF	24974	26122	25548	2.87	3.00	2.94
SEm±	371	411	277	0.05	0.05	0.03
CD (P = 0.05)	1051	1164	775	0.13	0.14	0.10

Table 4.2.1. Interaction effect of genotypes and fertility levels on plant height at 60 DAS

Fertility levels	Genotypes								
	2003			2004			Pooled		
	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14
50% RDF	153.32	148.69	139.82	154.67	156.12	147.47	153.99	152.40	143.65
75% RDF	179.13	171.25	163.14	187.37	172.17	168.76	183.25	171.72	165.95
100% RDF	184.17	173.53	167.97	191.04	176.76	172.53	187.61	175.14	170.25
125% RDF	191.34	171.75	172.90	198.55	174.05	174.17	194.95	172.90	173.94
		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)
Fertility levels at same genotype		3.92	11.13		3.59	10.19		2.66	7.46
Genotypes at same or different levels of fertility		5.08	14.42		4.59	13.03		3.12	8.76

Table 4.3.1 Interaction effect of genotypes and fertility levels on dry matter production (g plant⁻¹) at 60 DAS

Fertility levels	Genotypes								
	2003			2004			Pooled		
	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14
50% RDF	28.74	26.47	24.43	28.05	25.45	26.13	28.40	25.96	25.28
75% RDF	36.54	33.31	31.48	37.84	33.16	32.84	37.19	33.24	32.16
100% RDF	41.97	38.09	35.64	42.02	37.91	36.93	41.99	38.00	36.29
125% RDF	44.28	40.42	38.08	44.71	38.97	43.79	44.49	39.70	40.93
		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)
Fertility levels at same genotype		0.69	1.95		0.72	2.03		0.49	1.39
Genotypes at same or different levels of fertility		0.89	2.52		0.89	2.51		0.63	1.76

Table 4.3.2 Interaction effect of genotypes and fertility levels on dry matter production (g plant⁻¹) at harvest

Fertility levels	Genotypes								
	2003			2004			Pooled		
	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14
50% RDF	55.19	52.23	50.01	58.01	54.65	49.77	56.60	53.44	49.89
75% RDF	67.22	63.27	61.39	68.66	59.51	57.66	67.94	61.39	59.52
100% RDF	70.70	66.79	64.76	72.85	62.89	72.40	71.78	64.84	68.58
125% RDF	72.04	69.59	68.21	73.97	70.93	75.40	73.00	70.26	71.80
		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)
Fertility levels at same genotype		1.92	5.44		1.58	4.48		1.24	3.49
Genotypes at same or different levels of fertility		2.24	6.35		1.80	5.30		1.40	4.00

Table 4.6.1. Interaction effect of genotypes and fertility levels on grain yield (q ha⁻¹) of sorghum

Fertility levels	Genotypes								
	2003			2004			Pooled		
	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14
50% RDF	27.90	24.38	31.58	28.47	23.90	32.87	28.18	24.14	32.23
75% RDF	31.90	28.97	39.11	33.73	29.30	41.36	32.82	29.13	40.24
100% RDF	36.62	33.33	44.98	38.84	34.53	46.65	37.73	33.93	45.82
125% RDF	36.92	33.10	45.63	37.82	34.71	48.81	37.36	33.91	47.22
		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)
Fertility levels at same genotype		0.87	2.47		0.94	2.65		0.64	1.79
Genotypes at same or different levels of fertility		1.13	3.20		1.11	3.15		0.79	2.22

Table 4.7.1. Interaction effect of genotypes and fertility levels on nitrogen content (%) in grain

Fertility levels	Genotypes								
	2003			2004			Pooled		
	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14
50% RDF	1.32	1.31	1.57	1.35	1.33	1.62	1.334	1.319	1.595
75% RDF	1.38	1.37	1.70	1.41	1.38	1.75	1.397	1.377	1.721
100% RDF	1.40	1.39	1.74	1.42	1.40	1.79	1.410	1.394	1.766
125% RDF	1.42	1.41	1.79	1.45	1.42	1.83	1.437	1.414	1.813
		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)
Fertility levels at same genotype		0.015	0.044		0.015	0.042		0.011	0.030
Genotypes at same or different levels of fertility		0.020	0.057		0.017	0.049		0.013	0.037

Table 4.7.3. Interaction effect of genotypes and plant geometry on phosphorus content (%) in fodder

Genotypes	Plant geometry								
	2003			2004			Pooled		
	45 x 15 cm	45 x 10 cm	30 x 10 cm	45 x 15 cm	45 x 10 cm	30 x 10 cm	45 x 15 cm	45 x 10 cm	30 x 10 cm
CSV 15	0.20	0.19	0.19	0.21	0.20	0.19	0.203	0.194	0.189
SPV 1430	0.19	0.19	0.19	0.19	0.19	0.19	0.191	0.189	0.189
CSH 14	0.21	0.20	0.18	0.22	0.21	0.19	0.216	0.203	0.188
		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)
Plant geometries at same genotype		0.002	0.006		0.002	0.007		0.002	0.005
Genotypes at same or different plant geometry		0.002	0.006		0.002	0.006		0.002	0.005

Table 4.8.1. Interaction effect of genotypes and fertility levels on nitrogen uptake (kg ha⁻¹) by grain

Fertility levels	Genotypes								
	2003			2004			Pooled		
	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14
50% RDF	37.13	32.24	50.10	38.89	32.22	53.64	38.014	32.229	51.868
75% RDF	44.47	39.93	66.94	48.01	40.95	72.81	46.237	40.439	69.872
100% RDF	51.57	46.52	78.87	55.66	48.70	84.19	53.617	47.613	81.528
125% RDF	52.84	46.86	82.34	55.42	49.68	90.18	54.133	48.268	86.262
		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)
Fertility levels at same genotype		1.21	3.44		1.50	4.25		0.97	2.71
Genotypes at same or different levels of fertility		1.72	4.87		1.75	4.95		1.23	3.44

Table 4.8.2. Interaction effect of genotypes and plant geometry on nitrogen uptake (kg ha⁻¹) by grain

Genotypes	Plant geometry								
	2003			2004			Pooled		
	45 x 15 cm	45 x 10 cm	30 x 10 cm	45 x 15 cm	45 x 10 cm	30 x 10 cm	45 x 15 cm	45 x 10 cm	30 x 10 cm
CSV 15	58.18	48.83	32.50	62.65	52.82	33.02	60.413	50.826	32.761
SPV 1430	51.40	43.70	29.06	55.31	45.51	27.85	53.356	44.601	28.455
CSH 14	87.52	71.94	49.23	95.42	76.81	53.38	91.467	74.374	51.307
		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)
Plant geometries at same genotype		1.82	5.47		1.34	4.03		1.13	3.26
Genotypes at same or different plant geometry		1.36	4.08		1.16	3.47		0.95	2.72

Table 4.8.3. Interaction effect of genotypes and fertility levels on total N uptake (kg ha⁻¹) by crop

Fertility levels	Genotypes								
	2003			2004			Pooled		
	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14
50% RDF	84.29	74.45	88.48	88.06	75.79	93.77	86.176	75.120	91.127
75% RDF	101.84	92.32	116.00	106.33	92.57	124.05	104.084	92.445	120.023
100% RDF	116.56	105.29	135.79	122.31	108.54	143.34	119.436	106.918	139.567
125% RDF	128.00	114.29	146.72	128.97	115.84	154.87	128.488	115.064	150.795
		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)
Fertility levels at same genotype		2.45	6.94		2.78	7.89		1.85	5.19
Genotypes at same or different levels of fertility		2.96	8.40		3.06	8.67		2.13	5.97

Table 4.9.1. Interaction effect of genotypes and fertility levels on P uptake (kg ha⁻¹) by grain

Fertility levels	Genotypes								
	2003			2004			Pooled		
	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14
50% RDF	8.34	7.12	10.13	8.25	6.60	10.42	8.297	6.858	10.278
75% RDF	10.38	9.19	13.18	10.59	8.82	13.81	10.487	9.005	13.496
100% RDF	12.26	10.99	15.72	12.60	10.74	16.34	12.432	10.862	16.030
125% RDF	12.81	11.23	16.37	12.75	11.18	17.49	12.782	11.203	16.929
		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)
Fertility levels at same genotype		0.316	0.897		0.323	0.917		0.226	0.634
Genotypes at same or different levels of fertility		0.420	1.200		0.391	1.113		0.223	0.814

Table 4.10.1. Interaction effect of genotypes and fertility levels on protein content (%) in grain

Fertility levels	Genotypes								
	2003			2004			Pooled		
	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14
50% RDF	8.23	8.20	9.83	8.45	8.29	10.11	8.340	8.243	9.971
75% RDF	8.64	8.56	10.61	8.82	8.65	10.91	8.731	8.606	10.759
100% RDF	8.74	8.68	10.88	8.88	8.75	11.19	8.813	8.714	11.036
125% RDF	8.88	8.79	11.19	9.08	8.89	11.47	8.981	8.839	11.331
		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)
Fertility levels at same genotype		0.096	0.272		0.092	0.260		0.066	0.186
Genotypes at same or different levels of fertility		0.131	0.360		0.110	0.300		0.079	0.229

Table 4.10.2. Interaction effect of genotypes and fertility levels on protein yield (kg ha⁻¹) by grain

Fertility levels	Genotypes								
	2003			2004			Pooled		
	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14	CSV 15	SPV 1430	CSH 14
50% RDF	232.09	201.50	313.13	243.08	201.37	335.22	237.586	201.433	324.177
75% RDF	277.92	249.55	418.37	300.04	255.94	455.03	288.980	252.742	436.703
100% RDF	322.34	290.76	492.92	347.88	304.40	526.18	335.108	297.581	509.549
125% RDF	330.28	292.86	514.65	346.38	310.49	563.62	338.331	301.677	539.137
		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)
Fertility levels at same genotype		7.59	21.52		9.37	26.58		6.03	16.91
Genotypes at same or different levels of fertility		10.75	30.47		10.92	30.97		7.66	21.47

Table 4.10.3. Interaction effect of genotypes and plant geometry on protein yield (kg ha⁻¹)

Genotypes	Plant geometry								
	2003			2004			Pooled		
	45 x 15 cm	45 x 10 cm	30 x 10 cm	45 x 15 cm	45 x 10 cm	30 x 10 cm	45 x 15 cm	45 x 10 cm	30 x 10 cm
CSV 15	363.63	305.19	203.15	391.54	330.14	206.36	377.583	317.662	204.757
SPV 1430	321.27	273.11	181.63	345.68	284.41	174.06	333.474	278.757	177.844
CSH 14	546.99	449.62	307.70	596.35	480.06	333.640	571.668	464.840	320.666
		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)
Plant geometries at same genotype		11.41	34.20		8.41	25.20		7.09	20.41
Genotypes at same or different plant geometry		8.50	25.47		7.24	21.69		5.91	17.02

Appendix-I. Mean weekly meteorological parameters during crop growing season (2003 and 2004)

Std. week No.	Dates	Temperature (°C)				R.H. (%)				Sunshine (hrs day ⁻¹)		Evaporation (mm day ⁻¹)		Rainfall (mm)	
		Max.		Min.		Max.		Min.		2003	2004	2003	2004	2003	2004
		2003	2004	2003	2004	2003	2004	2003	2004						
27	Jul., 02-Jul., 08	33.2	34.0	25.4	24.7	88	76	65	55	5.4	5.3	9.7	6.8	25.0	23.4
28	Jul., 09-Jul., 15	31.0	32.1	24.2	25.1	91	74	75	54	5.8	5.3	5.6	7.5	57.7	0.0
29	Jul., 16-Jul., 22	31.8	33.5	24.7	24.2	90	80	68	55	6.4	8.1	4.2	7.3	16.3	60.1
30	Jul., 23-Jul., 29	28.9	33.4	23.4	25.2	97	72	88	52	3.1	6.5	5.2	5.9	164.9	1.5
31	Jul., 30-Aug., 05	28.2	30.3	22.7	23.4	93	95	80	72	4.2	2.4	4.7	3.3	11.2	110.6
32	Aug., 06-Aug., 12	30.4	30.1	23.6	23.7	93	83	79	81	4.6	1.2	1.5	3.1	12.6	54.8
33	Aug., 13-Aug., 19	31.1	28.6	24.2	23.1	85	95	67	80	6.5	1.6	6.3	3.7	0.0	68.2
34	Aug., 20-Aug., 26	30.8	29.5	23.8	23.2	88	87	79	72	3.9	2.1	3.5	4.5	85.9	51.2
35	Aug., 27-Sept., 02	28.4	29.5	22.9	22.3	90	84	78	61	2.3	8.3	3.3	6.8	20.1	0.0
36	Sept., 03-Sept., 09	30.4	32.5	22.3	21.3	83	82	60	73	8.4	8.2	4.7	3.9	0.2	25.2
37	Sept., 10-Sept., 16	30.8	31.4	21.6	22.1	83	82	64	52	8.7	8.9	4.3	5.2	2.4	0.0
38	Sept., 17-Sept., 23	31.5	33.0	22.2	21.8	92	85	84	62	4.4	7.4	1.5	3.8	56.8	46.4
39	Sept., 24-Sept., 30	31.7	33.9	21.0	21.8	89	85	61	53	7.9	6.7	4.1	3.6	6.6	80.4
40	Oct., 01-Oct., 07	32.8	31.5	16.9	20.3	81	93	51	57	10.5	7.0	1.4	4.2	6.2	47.8
41	Oct., 08-Oct., 14	33.3	30.4	16.6	17.8	74	91	33	43	10.6	8.5	2.3	4.1	0.0	0.0
42	Oct., 15-Oct., 21	33.0	31.2	14.4	14.4	82	70	22	20	10.1	9.2	0.9	3.7	0.0	0.0
43	Oct., 22-Oct., 28	32.6	31.6	12.7	13.0	67	69	18	23	10.2	9.3	1.0	4.3	0.0	0.0
44	Oct., 29-Nov., 04	31.8	30.0	14.6	12.7	69	76	27	29	10.0	7.9	1.0	3.1	0.0	0.0

Source : Agromet observatory, Rajasthan College of Agriculture, Udaipur

Table 5.1 : Correlation coefficients and regression equations showing relationship between independent variable (X) and dependent variable (Y) on pooled basis

S. No.	Dependent (Y)	Independent (X)	Correlation coefficient (r)	r ²	Regression equation (Y = a+ b X)
1	DMA at 90 DAS	Plant height at 90 DAS	0.822**	0.676	Y = - 53.983 + 0.534 X
2	DAM at harvest	Plant height at harvest	0.723**	0.522	Y = - 37.092 + 0.471 X
3	Grain yield	Plant height at harvest	0.399*	0.159	Y = - 1.306 + 0.170 X
4	Fodder yield	Plant height at harvest	0.490**	0.240	Y = 24.761 + 0.438 X
5	Biological yield	Plant height at harvest	0.720	0.518	Y = 23.455 + 0.608 X
6	Grain yield	DMA at 90 DAS	0.740**	0.547	Y = 5.616 + 0.496 X
7	Grain yield	DMA at harvest	0.821**	0.674	Y = 0.816 + 0.537 X
8	Grain yield	Length of panicle (cm)	0.661**	0.437	Y = - 23.656 + 2.184 X
9	Grain yield	Weight of panicle (cm)	0.926**	0.857	Y = - 50.356 + 0.930 X
10	Grain yield	Grain weight of panicle (g)	0.950**	0.902	Y = - 45.029 X 1.062 X
11	Grain yield	No. grains panicle	0.897**	0.805	Y = - 77.345 + 0.040 X
12	Grain yield	Test weight	0.939**	0.881	Y = - 37.244 + 2.711 X
13	Fodder yield	DMA at 90 DAS	-0.031	0.001	Y = 121.479 – 0.044 X
14	Fodder yield	DMA at harvest	-0.107	0.011	Y = 128.233 – 0.146 X
15	Biological yield	DMA at 90 DAS	0.340*	0.116	Y = 127.095 + 0.452 X
16	Biological yield	DMA at harvest	0.301	0.091	Y = 129.049 + 0.391 X
17	Weight of panicle (cm)	Length of panicle (cm)	0.813**	0.662	Y = 19.878 + 2.676 X

S. No.	Dependent (Y)	Independent (X)	Correlation coefficient (r)	r²	Regression equation (Y = a+ b X)
18	Grain weight of panicle (g)	Length of panicle (cm)	0.756**	0.572	Y = 15.288 + 2.236 X
19	No. grains panicle	Length of panicle (cm)	0.697**	0.486	Y = 1435.660 + 52.260 X
20	Test weight	Length of panicle (cm)	0.486**	0.236	Y = 11.745 + 0.556 X
21	Grain weight of panicle (g)	Weight of panicle (cm)	0.990**	0.979	Y = - 6.243 + 0.889 X
22	No. grains panicle	Weight of panicle (cm)	0.919**	0.844	Y = 918.437 + 20.930 X
23	Test weight	Weight of panicle (cm)	0.805**	0.648	Y = 0.965 + 0.280 X
24	Test weight	No. grains panicle	0.821**	0.673	Y = - 8.908 + 0.013 X
25	Grain yield	N uptake in grain	0.971**	0.942	Y = 10.743 + 0.452 X
26	Grain yield	P uptake in grain	0.994**	0.989	Y = 6.886 + 2.453 X
27	Protein yield	P uptake in grain	0.979**	0.959	Y = - 35.985 + 32.416 X
28	Fodder yield	N uptake in straw	0.738**	0.545	Y = 35.352 + 1.475 X
29	Fodder yield	P uptake in straw	0.939**	0.881	Y = 13.18 + 4.52 X
30	Biological yield	Total N uptake in straw	0.392*	0.153	Y = 120.895 + 0.300 X
31	Biological yield	Total P uptake in straw	0.823**	0.677	Y = 57.928 + 2.764 X

