

**RESPONSE OF COWPEA (*Vigna unguiculata* L.)
GENOTYPES TO SOWING WINDOWS AND PLANTING
GEOMETRY UNDER NORTHERN TRANSITIONAL ZONE OF
KARNATAKA**

**Thesis submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfillment of the requirements for the
Degree of**

Master of Science (Agriculture)

In

Agronomy

By

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JUNE, 2014

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INTRODUCTION

Pulses, popularly known as “poor man’s meat”, constitute the major source of dietary protein of the large section of vegetarian population of the world. On an average, pulses contain 20 to 30 per cent protein. Apart from their high nutritional value, they have a unique characteristic of maintaining and restoring soil fertility through biological nitrogen fixation as well as complete defoliation adding to soil as organic manure thus play a vital role in sustainable agriculture (Asthana, 1998). India is the largest producer and consumer of pulses in the world accounting 33 per cent of world area and 22 per cent of production (Anon., 2011). Production of pulses however, does not commensurate with the demand in the country. It is estimated that the country’s population will reach nearly 1350 million by 2020 A.D (Anon., 2011), then country would need a minimum of 33.3 million tonnes of pulses to meet the requirement. Infact, there has been stagnation in the production and productivity in pulses over the past two decades. There has been a diversion of acreage from pulses to cereals as a result of “Green Revolution” brought by the high yielding varieties of cereals. This is mainly due to the low yield potential of pulses and instability.

The important pulse crops grown in India are chickpea, pigeonpea, greengram, blackgram, cowpea, lentil, and pea. Among the pulses, cowpea (*Vigna unguiculata* L.) belongs to the family *Fabaceae* (*leguminosae*) and subfamily of *papillnoideae*. It is one of the important versatile food legumes and a valuable component of the traditional cropping systems in the semi-arid tropics covering Asia, Africa and Central America. It is the most ancient human food crop. From the production of this crop, rural families variously derive food, animal feed, and income for their lively hood. Its quick growth, rapid ground cover and nitrogen fixing ability (56 kg ha^{-1}) have made it an essential component of sustainable agriculture in marginal lands. The average minimum rainfall required for the crop is 300 mm over the growing season. It is ideally suited to tropical lowland, doing well in hot, dry and humid ecosystems (Nwokolo and Smart, 1996).

It is an important multipurpose grain legume extensively cultivated in arid and semiarid tropics. The estimated world wide area under cowpea is over 14 million hectares, with production of 4.5 million tonnes and productivity of 387 kg ha^{-1} (Anon., 2009). In India, cowpea is grown in an area of 3.9 million hectares with a production of 2.21 million tonnes (Anon., 2012). In Karnataka, the crop is grown in an area of 0.84 lakh hectares with a production of 0.25 lakh tonnes. The productivity of cowpea in Karnataka is low (360 kg ha^{-1}) as compared to the national productivity of 567 kg ha^{-1} (Anon., 2013). This clearly indicates the necessity to identify the reasons for such low productivity of cowpea in India in general and Karnataka in particular.

Cowpea is grown as catch crop, mulch crop, intercrop, mixed crop and green manure crop. Cowpea has been intercropped for long time with various other crops such as maize, sorghum and millets. It can be utilized in various ways ranging from the use of young green seedling as vegetables and also forage for livestock to its consumption as beans, the green pods are used as vegetables (Ekpo *et al.*, 2012). It is good source of protein (20-25 %), which is enriched by amino acids like lysine and tryptophan. It is very nutritious with free metabolites or other toxins (Kay, 1979). Despite the importance of cowpea in sustaining livelihood of the rural communities, seed yield of the crop has always remained low and variable. Poor production practices like choice of cultivar, adaptability as well as lack of information on the suitable planting date for new genotypes has contributed to low cowpea productivity.

There are diverse cowpea genotypes demanding a site specific management approach which includes choice of proper planting date and a selection of best adapted genotype. Climate has been changing world over and negatively affecting crop productivity in most parts of the world. Rainfall onset and distribution has changed. This has an effect on the optimum planting time of crops and resulted reducing in yield because of inappropriate planting dates. Among various marginalized crops, cowpea is the most affected due to its growth habit and susceptible to biotic stress. The crop is adapted to harsh environments such as high temperatures and drought, but yield can be compromised by low or high rainfall regimes. Optimum sowing date is a non cash input which enhances the yield potential of the crop. Suitable time of sowing provides optimum growing conditions with favourable temperature, light, humidity and rainfall during crop growth period. This ultimately decides the selection of varieties for particular or different dates of sowing to stabilize or to get maximum yield. The changes to the onset of rainfall have necessitated a re-looked to the recommended planting dates of many crops since they are now unsuitable to prevailing rainfall patterns.

The lack of high yielding cultivars, which are drought tolerant and resistant to pests and diseases, as well as the unavailability of guaranteed market to dispose excess produce slowly relegated this nutritious pulse. Low seed yield can be attributed to unfavourable agronomic practices by farmers such as selection of suitable planting date and planting geometry. These are the challenges for researchers to find the most appropriate planting date using high yielding and early maturing and determinate varieties of cowpea. Varietal requirements of cowpea in terms of plant type, seed colour, maturity date and usage patterns are extremely diverse from region to region, and approaching breeding programs for cowpea is more complex than other crops.

Over the many years high yielding varieties with variations in growth habits have been developed. Introduction of such high yielding varieties has provided the scope for improving overall productivity of cowpea. Yield potentiality of cowpea can be fully harnessed with suitable combination of agronomic practices and recommended high yielding varieties. The ruling cultivar of cowpea in northern transition zone of Karnataka is C-152 which is having indeterminate growth habit and highly susceptible to rust disease. This variety has a tendency of producing excessive vegetative growth on black soil with ample soil moisture resulting in poor seed yield. In this regard, attempts were made to develop a determinate, early maturing and high yielding genotype which results in development of genotype DC 15. At present it is under AVT II stage in co-ordinated trails. In order to generate information on performance of this genotype to agronomic management practices particularly with respect to different sowing windows and planting geometry the present investigation is carried out with the following objectives

Objectives of the investigation

1. To evaluate comparative performance of determinate and indeterminate cowpea genotypes
2. To study response of cowpea genotypes to sowing windows and planting geometry
3. To workout economics of cowpea cultivation

REVIEW OF LITERATURE

An attempt has been made to review the work carried out in respect of “Response of Cowpea Genotypes to Sowing Windows and Planting Geometry under Northern Transitional Zone of Karnataka during *kharif*-2013”.

2.1 Cowpea varietal performance

Varieties play an important role in determining the yield potentiality of crop. The potential yield of varieties within its genetic limit is set by its environment. The release of high yielding varieties of pulses is a major breakthrough in achieving increase in pulse production per unit time. Varieties differ in their yield potential depending on many physiological processes, which are controlled by both genetic makeup and the environment.

Birari *et al.* (1993) at Dapoli observed that among seven promising genotypes, the high yielding genotypes were V-16 (9.39 g plant⁻¹) and ACCC-210 (8.17 g plant⁻¹). ACCC-210 showed a high degree of predictability for pods plant⁻¹, pod length, 100-grain weight and harvest index and was rated as the most stable genotype.

At Port Blair, Ram *et al.* (1994) evaluated twenty-seven *Vigna unguiculata* varieties during 1985 and 1986. Among the varieties higher seed yields were recorded with cv. Y2 (1.16 t ha⁻¹), RC-48 (1.25 t ha⁻¹), RC-48 (1.25 t ha⁻¹) and C-152 (1.2 t ha⁻¹).

Jadhav *et al.* (1995) found that genotype V-240 was found to be significantly superior in terms of plant height, pod number and test weight over PS-16 genotype.

Vishwanath and Nadarajan (1996) conducted an experiment to study the genotype and environment interaction of grain yield in cowpea. Varieties IT-86-D-1056 and CO-4 showed average response to changes in environmental conditions with higher mean yield against the population mean yield. VCP-4 had the higher mean seed yield among the materials studied and was especially suited for the unfavourable growing season.

Vishwanath *et al.* (1997) reported that Vamban-1 cowpea is a pureline selection from IT85-F2020. It matures in 55-65 days and is erect, with an average height of 25-30 cm. The average seed yield is 750 kg ha⁻¹ under rainfed condition. Being white seeded, Vamban-1 has an edge over other varieties in market preference.

Among cowpea genotypes belonging to different growth habit determinate genotypes had higher values of photosynthetic rate, transpiration rate, stomatal conductance, as compared to the indeterminate genotypes. The genotypes KM-5 and KM-4 (determinate) and C-44 and C-22 (indeterminate) recorded higher values for photosynthetic rate, transpiration rate and seed yield (Kalpana, 2000).

Nirmal *et al.* (2001) reported that yield potential of IHR Sel-11 and Sel-2-1 genotype was higher among 20 tested cultivars at Varanasi. Significantly higher protein content was recorded in local genotypes like red seeded climbing cowpea local-1 (24.9 %) and Kasajhambla (23.5 %, bush type).

Ahmed *et al.* (2010) reported that the local cultivar (buff) had a significantly higher leaf area index (1.16), number of pods plant⁻¹(8.8), heavier 100-seed weight (13.9 g), greater final seed yield (1.22 t ha⁻¹) and late in maturity as compared to Hydoob and Ein Elgaza (improved cultivars).

Akbar Khan *et al.* (2010) conducted research to study the performance of 24 exotic cowpea genotypes. Genotypes were evaluated for, plant height, days to maturity, seeds pod⁻¹, 100-seed weight and seed yield. The genotype namely SADANDY was early maturing (97 days), while 3 CCP 915 was late maturing (124 days). Significantly higher seed yield of 3550 kg ha⁻¹ was recorded with CP 140 while minimum of 317 kg ha⁻¹ was recorded with 4CCP 931. The genotype CP 140 ranked first by producing significantly higher yield and was early maturing than other genotypes.

Shiringani and Shimelis (2011) studied the relative yield response and stability among ten selected improved cowpea genotypes to make recommendation for wide or specific adaptation. Average yield in cowpea varied from 2583 to 3998 kg ha⁻¹ and they are significantly differed. Genotypes Pan311, CH14 and IT18E-16 recorded seed yield of 3998, 3777, and 3751 kg ha⁻¹, respectively.

A study was conducted to determine the performance of three cowpea varieties (Aiyi, Bengla and UCC-Early) to different plant density levels low, medium and high (125 X 103, 1667.7 X 103 and 250 X 103 plants ha⁻¹ respectively). The variety Aiyi produced significantly higher dry matter (231.9 g m²) and yield (251 g m²) compared to Bengla (214.2 and 198.3 g m² respectively) and UCC-Early (184.1 and 145.3 g m² respectively). Total dry matter production increased linearly with increasing plant density (Addo-Quaye *et al.*, 2011).

Ugur Basaran *et al.* (2011) conducted research on nine cowpea genotypes (two released cultivars and seven lines) and evaluated for growth and yield parameters and yield (plant height, number of branches plant⁻¹, pod length, seed number pod⁻¹, thousand seed weight and seed yield). Results indicated that line G-1 had significantly higher plant height (122.4cm) and number of seeds pod⁻¹ (10) than the other genotypes. Seed yield ranged from 1010 to 1420 kg ha⁻¹. Significantly higher thousand seed weight and seed yield obtained in genotype Karagoz (233.2 g and 1420 kg ha⁻¹ respectively) over other genotypes.

Agbogidi and Egho (2012) conducted study to evaluate eight varieties of cowpea (IT80D-699, IT82 (e-18), Ife Brown, IT870-9411 and TVX3236, IT90K-277-2, IT870-9411 and IT828-146). Results showed that significant differences existed among the varieties tested in all the growth characters measured (plant height, number of leaves and leaf area). Ife Brown, IT8482246-4 and TVX3236 varieties performed significantly better both in the growth and yield as well as yield related parameters when compared to IT800D-699, IT82(e-18), IT870-9411 and IT828-146 varieties.

Olotuah and Fadare (2012) reported that variety Ife Brown recorded the higher protein content of 36.75 per cent and it was observed that there were significant differences on the growth parameters over the varieties Drum, Sokoto, Oloyin and Erusu.

Praveen Kumar *et al.* (2013) conducted experiment to study morphological and genetic variation in forty cowpea genotypes and revealed that the seed yield plant⁻¹ showed significant and positive association with plant height, number of clusters, number of pods, pod length and number of seeds pod⁻¹ while it was negatively correlated with primary branches and 100 seed weight.

Jakusko *et al.* (2013) reported the variety IT89KD-391 recorded significantly higher growth parameters and seed yield of 1241 kg ha⁻¹ over the varieties T89KD-288 (1195 kg ha⁻¹) and IT97K-499-35 (1056 kg ha⁻¹).

Sah *et al.* (2013) conducted experiment to study the growth and productivity of cowpea genotypes. The results indicated that Surya variety produced significantly higher grain yield (1.07 t ha⁻¹) compared to Prakash (0.91 t ha⁻¹).

2.1.1 Varietal performance of other pulses

Patil and Patil (1991) conducted study on mungbean genotypes and observed that Type-44 genotype recorded significantly higher plant height, number of branches plant⁻¹, stover yield and grain yield (937 kg ha⁻¹) over Gujarat-2 (790 kg ha⁻¹).

Among five black gram genotypes, genotype LBG-625 recorded significantly higher seed yield (1168 kg ha⁻¹), 100 seed weight (5.97g) and total number of pods (36.88 plant⁻¹) followed by K-3 and IPU-982 with respect to yield and yield attributing characters in southern transitional zone (Anon., 2001). Similarly, studies conducted at Regional Research Station, Shimoga (Karnataka) revealed that among nine genotypes tested, MI-7-21 recorded numerically higher grain yield (1370 kg ha⁻¹) followed by ML-131 (1278 kg ha⁻¹), KDM -1 (1167 kg ha⁻¹) and PDM -84-178 (1130 kg ha⁻¹) (Anon., 1991a and 1991b).

Thakur Singh and Dhingra (1993) observed that mungbean genotype ML-131 recorded higher plant height, number of primary and secondary branches and significantly higher grain yield (15.6 q ha⁻¹) than ML-322 (14.4 q ha⁻¹).

Studies conducted at Agricultural Research Station (ARS) Bheemaranagudi, revealed that among the twelve entries of blackgram, the variety BRB-3 produced higher yield (13.66 q ha⁻¹) followed by TAU-1 (13.50 q ha⁻¹), Manikya (13.3 q ha⁻¹) and K-3 (13.33 q ha⁻¹). At ARS, Bidar also BRB-3 produced significantly higher yield (21.04 q ha⁻¹) compared to Manikya (18.37 q ha⁻¹) and K-3 (20.14 q ha⁻¹) (Anon., 1994).

An experiment was carried out under rainfed condition at Kirei (Orissa) during *kharif* 1992-93, and it was found that blackgram genotype Sarala recorded significantly higher yield (1270 kg ha⁻¹)

compared to S-37 (1160 kg ha⁻¹) and was on par with that of T-9 (1225 kg ha⁻¹) (Mohapatra *et al.*, 1996).

Ihsanullah *et al.* (2002) conducted experiment on *kharif* mash bean varieties and reported that NARC Mash-1 recorded significantly higher number of pods plant⁻¹ (20) and grain yield (557 kg ha⁻¹) over NARC Mash-3 and NARC Mash-4 varieties.

Soomro and Khan (2003) studied three mungbean genotypes to identify the grain yield and yield attributing characters and reported that the genotype NCM-209 was recorded significantly higher grain yield (1668 kg ha⁻¹) followed by NM-2 (1512 kg ha⁻¹) over other genotypes (NM-92, M-1 and M-6).

Anil Kumar and Reena (2007) conducted experiment to assess grain yield potential of mungbean genotypes and reported that genotype SMS-1 recorded significantly higher grain yield (1042 kg ha⁻¹) over other varieties PDM-54 and ML-131.

Guriqbal Singh and Sekhon (2007) conducted field experiment on loamy sandy soil and reported that variety Pusa 9971 produced higher grain yield over others. However, variety Asha was the tallest variety with the higher biological yield and least grain yield, whereas the variety Pusa 9971 was superior to others with respect to yield, while SML 668, NM 92 and ML 818 were on par with each other.

Abu Kawsar *et al.* (2009) conducted experiment on four mungbean varieties (BINA moog2, BINA moog5, BINA moog6 and BINA moog7) to identify the suitable variety for getting maximum yield during summer season. Varieties differed significantly with respect to yield. Among the varieties, BINA moog7 ranked first in terms of seed yield (938 kg ha⁻¹) followed by BINA moog6 (711 kg ha⁻¹), BINA moog5 (684 kg ha⁻¹) and BINA moog2 (547 kg ha⁻¹). BINA moog6 matured earlier than the other three varieties.

Guriqbal Singh *et al.* (2012) conducted experiment on urdbean genotypes and reported that genotype 'KUG 114' produced 5.9 and 22.2 per cent higher yield over 'KUG 173' and 'Mash 338', respectively. It was also recorded higher nodules plant⁻¹, dry weight of nodules plant⁻¹ and pods plant⁻¹ over the other two. 'KUG 114' required more or less higher GDD and PTU over the other two genotypes to attain 50 per cent flowering and physiological maturity.

Kamannavar *et al.* (2011) studied stability parameter of different greengram genotypes across the locations of Karnataka. On the basis of stability parameters, the top yielding genotypes such as DGGV-2 (964 kg ha⁻¹) DLGG-22 (945 kg ha⁻¹) and DGGs-16 (933 kg ha⁻¹) exhibit the stable performance across the environments. The genotypes BGS-9 (933 kg ha⁻¹), BPMP-1 (903 kg ha⁻¹) and KGS-83 (908 kg ha⁻¹) recorded higher yield across the locations but their performance was unstable due to significant deviation from regression. They concluded that DGGV-2, DLGG-22 and DGGs-16 were the most suitable and desirable genotypes which showed higher stable grain yields at different agro-climatic regions (Kamannavar *et al.*, 2011).

Madhu (2013) studied on response of mungbean genotypes to different dates of sowing and reported that mungbean genotype DGGV-2 recorded significantly higher growth parameters and yield parameters like number of pods plant⁻¹ (13.38), number of seeds pod⁻¹ (13.60), pod length (11 cm), thousand seed weight (48.70 g) and seed yield (1113 kg ha⁻¹) over genotype SEL-4 (11.46, 10.37, 9.65 cm, 45.52 g and 1021 kg ha⁻¹ respectively). Higher grain protein content (%) was recorded in DGGV-2 (21.63) followed by SEL-4 (21.32).

2.2 Response of cowpea to sowing dates

Optimum sowing date is a non cash input which enhances the yield potential of the crop. Suitable time of sowing provides optimum growing conditions with favourable weather elements like temperature, light, humidity and rainfall during the crop growth period.

The study demonstrate at Nigeria on cowpea genotypes, planting date and growing environments indicated that, planting date caused large differences in flowering time among genotypes. The best planting date to produce high seed yield in cowpea was November (Rhandzu, 2007).

Kaki Ngodi *et al.* (2010) reported that sowing date significantly influenced the yield and yield components of cowpea. Cowpea sown on 8th august recorded significantly higher yield (5.93 t ha⁻¹) than 25th July sowing (5.05 t ha⁻¹).

Sah *et al.* (2013) studied effect of different sowing dates on growth and productivity of cowpea genotypes. The results indicated that the significantly higher pod yield (2.21 t ha^{-1}) and grain yield (1.14 t ha^{-1}) were obtained on 21st August sown crop as compared to 6th August and 6th September.

The information on response of cowpea to different sowing dates is meagre. Hence the response of other pulses to different dates of sowing is reviewed subsequently.

2.2.1 Response of other pulses to sowing dates

Ihsanullah *et al.* (2002) conducted experiment on mashbean to study the effects of sowing dates on yield and yield components and reported that biological yield was maximum during June 15th (6000 kg ha^{-1}) sowing followed by July 1st (5439 kg ha^{-1}). Number of pods plant⁻¹, number of seeds pod⁻¹, 100- seed weight, grain yield (kg ha^{-1}) recorded higher value of 30, 5, 4.26 and 825 respectively for July 1st sowing.

Soomro and Khan (2003) conducted experiment on mung bean genotypes to study the effects of different sowing dates on grain yield and yield attributing components and reported that delay in sowing caused substantial decrease in all the growth parameters. The genotypes sown early (5th July) recorded significantly higher grain yield of 1298 kg ha^{-1} over the other sowing dates (15th July, 25th July and 5th August). Early sowing produced 41 and 86 percent higher grain yield over late sowing.

Singh *et al.* (2003) noticed that sowing between 12th and 24th July was the optimum time for getting better yield in mungbean. They further observed that the crop sown on 8th July recorded significantly higher grain yield than the crop sown on 16th, 24th July and 1st August. The sowing on 16th July was superior to 24th July in term of grain yield while 24th July and 1st August sowings were at par with respect to grain yield. 10th August sowing recorded significant reduction in grain yield.

Fraz *et al.* (2006) observed that yield attributes of mung bean were higher during 3rd week of July sowing than 3rd week of June and 1st week of July sowing. July 3rd week sown crop recorded significantly higher grain yield (1259 kg ha^{-1}) as compared to 1st week of July (1099 kg ha^{-1}) and 3rd week of June (815 kg ha^{-1}).

Asghar Malik *et al.* (2006) studied effect of sowing dates on growth and yield of mungbean and reported that significantly higher seed yield was recorded during third week of July sowing (1259 kg ha^{-1}) over 1st week of July (1099 kg ha^{-1}) and third week of June (815 kg ha^{-1}) sowing.

Results of two years field experiment conducted during 2005 and 2006 on mungbean at Iran showed that seed yield was significantly affected by sowing dates. The higher seed yield (103 g m^{-2}) was obtained on June 29th sowing due to higher number of pods plant⁻¹ and 1000-seed weight as compared to June 14th and May 30th (Sadeghipour, 2008).

Rehman *et al.* (2009) studied the effect of five planting dates namely 30th March, 15th April, 15th May, 15th June and 15th July on two mung bean varieties. Higher grain yield was recorded with early planting of 30th March (981 kg ha^{-1}) over the other dates of sowing 15th April (912 kg ha^{-1}), 15th May (460 kg ha^{-1}), 15th June (523 kg ha^{-1}) and 15th July (532 kg ha^{-1}).

Rathore *et al.* (2010) observed that urdbean varieties sown at the onset of monsoon (7th July) recorded higher seed yield (1185 kg ha^{-1}) followed by the crop sown on 27th July (20 days after first sowing). The crop sown on 7th July registered 45 per cent higher yield over crop sown on 27th July. Similarly, urdbean sown on 7th July recorded significantly higher haulm yield (3415 kg ha^{-1}) over 27th July (2432 kg ha^{-1}).

Guriqbal Singh (2012) studied effect of time of planting on nodulation, growth and seed yield of urdbean genotypes and revealed that planting of urdbean during July 15th and 25th recorded higher seed yield (1355 and 1354 kg ha^{-1} respectively) than delayed planting on August 5th (901 kg ha^{-1}). Nodulation and pods plant⁻¹ was also higher in case of July 15th and July 25th planting over August 5th planting.

Nargis Jahan and Golam Adam (2012) reported that mungbean responded significantly to sowing time. Among the different dates, 15th April sown crop produced higher plant height (68.4 cm), leaves plant⁻¹ (29.33), total dry matter plant⁻¹ (17.99), branches plant⁻¹ (8.17), pods plant⁻¹ (11.33), pod length (8.78 cm), seeds pod⁻¹ (11.17), 1000 seed weight (46.52 g), seed yield plant⁻¹ (5.33 g), yield ha^{-1} (1.77 t) and harvest index (29.58 per cent) over others. The seed yield decreased by 36.8 and 49.9 per cent when seed sown early (15th March) or late (15th May) compared to April 15th due to production of lower yield components.

Reza Monem *et al.* (2012) observed that planting date had significant effect on many traits like grain yield, biomass, harvest index, and the number of seeds per pod. The first planting date (5th May) recorded significantly higher grain yield (479 g m⁻²) over 6th June (324.1 g m⁻²) and it was on par with 20th May (449.8 g m⁻²).

Madhu (2013) reported that early sowing (first fortnight of June) of mungbean recorded significantly higher seed yield (1268 kg ha⁻¹) over late sown condition (second fortnight of July). The increase in yield was 29.17 per cent. Early sowing resulted in significantly higher yield attributes like number of pods plant⁻¹ (18.36), thousand seed weight (47.71g), pod length (10.78 cm) and number of seeds pod⁻¹ (13.20) as compared to late of sowing.

2.3 Response of cowpea to planting geometry

For any genotype to express its potential it should be tried under optimum population level. Variation in the population causes changes in the light interception, humidity and temperature within canopies. Crop with wider row spacing tend to putforth a vigorous vegetative growth, while closer spacings tend to restrict the same. Optimum population level is the one, which provides the crop with the best environment to express its capacity fully under the given conditions. Therefore, there is a need to understand the relationship between plant density and yield so as to identify the optimum population.

At Dharwad, Patil *et al.* (1991) studied the performance of cowpea varieties at two interrow spacings. They observed that the higher yield (1.23 t ha⁻¹) was obtained by adopting 45 x 10 cm than 30 x 10 cm row spacing (1.06 t ha⁻¹).

Sharma (1991) revealed that planting of cowpea either at 30 or 45 cm was most optimum compared to close (22.5 cm) and wider spacing (60 cm).

Daljit Singh *et al.* (1992) reported that cowpea cultivar 263 recorded higher mean green pod yield from 30 x 15 cm row spacing with 2,20,000 plants ha⁻¹.

Rajesh Kumar *et al.* (1997) compared cv. V-130 and cv. GC-3 sown at 30, 45 and 60 cm between rows and 10, 15 and 20 cm within the rows. The cultivar GC-3 recorded higher grain yield than V-10. The higher yield was recorded with 45 cm row spacing (1.15 t ha⁻¹) followed by 30 (0.99 t ha⁻¹) and 60 cm (0.83 t ha⁻¹).

Abdelbagi *et al.* (2000) reported that higher seed yield was obtained at lower spacing *i.e.* 51 x 10 cm over 76 x 10 cm and 102 x 10 cm.

Choudhary and Bovasky (2001) reported the yield of 900 pounds per acre is achieved with 70,000 plants per acre planted in two rows per bed within row spacing of 5 inches in Texas Pinkeye Hull cowpea.

Shivakumar *et al.* (2002) conducted experiment to know the effect of intergenotypic competition on yield assessment at different spacings in cowpea. Seeds were sown at 5, 10, 20 and 40 cm distances in rows spaced 40 cm apart, the competition effect increased as the distance between plants decreased.

Yadav (2003) reported that row spacing had significant effect on plant height, yield attributes and seed and straw yield. Row spacing of 30 cm being at par with 45 cm spacing, produced significantly higher number of pods plant⁻¹ and seed yield than 60 cm. Increase in seed yield due to 30 and 45 cm row spacing over 60 cm spacing was 36.9 and 27.8 per cent, respectively.

Lemma *et al.* (2009) conducted study to examine the effects of planting density and inter-row spacing on cowpea productivity under irrigated condition and revealed that an increase in grain yield (3.96 t ha⁻¹), yield attributing characters and total biomass yield (8.84 t ha⁻¹) was observed with 50 cm row spacing (1, 60,000 plants ha⁻¹) and 70 cm spacing showed on par results (71428 plants ha⁻¹, 3.88 t ha⁻¹) under the wet regime.

Ahmad *et al.* (2010) studied effects of four intra-row spacing (50, 75, 100 and 125 cm) and three varieties (Dahab Elgoaze, Eien Elghzal and Buff) on growth and yield, and reported that the intra row-spacing of 50 cm produced significantly higher grain yield (1.59 t ha⁻¹). Buff was characterized by late maturing, high seed weight and high productivity.

Jakusko *et al.* (2013) reported decreasing plant population or increasing spacing from 45 x 25 cm to 75 x 25 cm significantly increased the number of pods plant⁻¹ from 12.77 to 15.74. Similarly,

length of pods plant⁻¹ significantly increased from 13.61 to 15.73 cm and number of seeds pod⁻¹ increased from 10.91 to 12.74. Seed yield was higher (1228 kg ha⁻¹) in spacing of 45 x 25 cm over 60 x 25 (1195 kg ha⁻¹) cm and 75 x 25 cm (1056 kg ha⁻¹).

2.3.1 Response of other pulses to planting geometry

Muhammad *et al.* (2000) studied the effect of different planting density on yield and yield components of mungbean. Crop was planted at 15, 30 and 45 cm row spacing with 5, 10 and 15 cm intra row spacing and reported that seed yield was significantly higher with 30 X 10 cm spacing (1089 kg ha⁻¹) than 45 X 15 cm spacing (981 kg ha⁻¹).

Ihsanullah *et al.* (2002) in mung bean reported that higher plant height (47.50 cm) was observed in 43 cm row spacing where plants were spaced 7 cm within rows. Significantly higher number of pods plant⁻¹ (28.25), number of seeds pod⁻¹ (10.25), 100-seed weight (4.27g), biological yield (3854 kg ha⁻¹) and grain yield (921 kg ha⁻¹) were recorded with row spacing of 20 cm where plants were spaced 15 cm within rows.

Azarakhash *et al.* (2007) conducted experiment to evaluate the effects of row spacings and inter row spacings on common bean. Results indicated that significantly higher grain yield was recorded at 30 cm row and 5 cm inter row spacing (4.2 t ha⁻¹) and it was on par with 45 x 5 cm spacing (3.9 t ha⁻¹). The number of pods plant⁻¹, number of seeds pod⁻¹ and seed weight plant⁻¹ increased as a result of decrease in row and inter row spacing.

Mureithi *et al.* (2012) conducted studies to evaluate the effect of intra-row spacing on growth of French bean and reported that increasing intra-row spacing from 10, 15 and 20 cm resulted in significant increase in all the growth parameters. Increase in spacing further to 30 cm between plants resulted in significant decrease in growth parameters.

2.4 Interaction effects

Famara Massaly (1991) reported that cowpea yields were significantly higher for the June plantings (May 30th and June 21st, 3022 and 3826 kg ha⁻¹ respectively) and lowest for the July 12th and August 4th planting. The low yields in the later plantings appeared to be related primarily to low water supply and cool night temperatures. Plants in the low population (15 plants 3 m⁻¹ row) communities had more vegetative branches and floral peduncles and produced larger pods with more seeds pod⁻¹ and pods plant⁻¹ than did those in the high population communities (60 plants per 3 m row).

Abdur Rahman *et al.* (2004) conducted experiment to study the effect of planting date and plant density on yield and yield attributes of five varieties of mungbean and reported that variety BARIMung-2 planted on 3rd February at plant density of 30x10 cm recorded significantly higher seed yield (1490 kg ha⁻¹) and harvest index (64.2 %) than BARIMung-3 planted on 20th march at plant density of 40x30 cm (233 kg ha⁻¹ and 13.7 % respectively).

Shivananda (2005) reported KM-5 genotype at 45 x 10 cm row spacing recorded significantly higher seed yield (1775 kg ha⁻¹) than C-152 at 30 x 10 cm (788 kg ha⁻¹) and 60 x 10 cm (868 kg ha⁻¹) row spacing.

Krishna, 2006, in cowpea reported that June second fortnight sowing with 30 cm row spacing recorded significantly higher seed yield (925 kg ha⁻¹), haulm yield (4442 kg ha⁻¹) and harvest index (0.20) over July first and second fortnight sowings than 45 cm row spacing.

BARIMung-2 planted at a spacing of 30 x 10 cm recorded significantly higher seed yield (1217 kg ha⁻¹) than BARIMung-5 planted at 20 x 20 cm (737.7 kg ha⁻¹) and 40 x 30 cm (557.7 kg ha⁻¹) spacing (Kabir and Sarkar, 2008).

Patel *et al.*, 2011, reported that significantly higher pod length, number of grains pod⁻¹ and green pod yield plant⁻¹ was recorded in 60 x 15 cm spacing with GC-3 variety than Pusa Phalguni, PusaKomal and Gujarat Cowpea-4 with either 30 or 45 cm row spacing.

Degri *et al.* (2012) reported that cowpea Borno brown and Banjiram planted early (14th August) recorded significantly higher seed yield (813 and 601 kg ha⁻¹) than late planting (21st August) (353 and 421 kg ha⁻¹ respectively). However there is no significant difference between the varieties with respect to yield planted either early or late.

Three mungbean varieties (NM-92, NM-98, and M-1) were grown at three inter-row spacings (30, 60 and 90 cm) to evaluate suitable variety with proper row spacing. Significantly higher seed yield was obtained with NM-98 variety at 30 cm spacing (727 kg ha^{-1}) over M-1 at 90 cm row spacing (676 kg ha^{-1}) (Rasul *et al.*, 2012).

Rima and Nabam (2013) reported that cowpea sown during second fortnight of June at 30 x 10 cm spacing recorded significantly higher seed yield (1054 kg ha^{-1}) than sown on first and second fortnight of July at 45 x 10 cm row spacing (741 kg ha^{-1}).

2.5 Economics

Shivananda (2005) reported that cowpea genotype KM-5 recorded significantly higher gross return, net return and Benefit: cost ratio ($20,739$, $12,343 \text{ ha}^{-1}$ and 2.50 respectively) over the genotype C-152 ($13,085$, $4,689 \text{ ha}^{-1}$ and 1.57 respectively). Significant differences were also observed due to row spacings. With 45 cm x 10 cm spacing recorded significantly higher gross return, net return and B:C ratio ($19,458$, $11,149 \text{ ha}^{-1}$ and 2.35 respectively) than 30 x 10 cm and 60 x 10 cm row spacing.

Sah *et al.* (2013) revealed that higher gross income ($57,372 \text{ ha}^{-1}$), net income ($41,189 \text{ ha}^{-1}$) and B:C ratio (3.54) were observed in 21st August sown crop as compared to 6th August and 6th September sown crop. Significantly higher gross income ($53,553 \text{ ha}^{-1}$) and B: C ratio (3.30) was obtained from variety Surya than variety Prakash because of higher yield recorded in variety Surya sown during 21st August.

Madhu (2013) studied response of mungbean genotypes to dates of sowing and reported that significantly higher gross return, net return and B:C ratio was obtained in the crop sown during first fortnight of June ($49,028$, $32,226 \text{ ha}^{-1}$ and 2.92 respectively) followed by second fortnight of June ($43,136$, $26,331 \text{ ha}^{-1}$ and 2.57 respectively) over late sown crop (second fortnight of July). However among the mungbean varieties DGGV-2 recorded significantly higher gross return, net return and B:C ratio ($43,060$, $26,145 \text{ ha}^{-1}$ and 2.55) over other mungbean genotypes.

MATERIAL AND METHODS

A field experiment was conducted to study the “Response of cowpea genotypes to sowing windows and planting geometry under northern transitional zone of Karnataka” during *kharif* 2013. The details of materials used and the techniques employed throughout the course of investigation are presented in this chapter.

3.1 Location of the experimental site

The experiment was conducted at the Main Agricultural Research Station (MARS), University of Agricultural Sciences (UAS), Dharwad, Karnataka, in plot number 151 of F Block during *kharif* 2013. Dharwad is situated at 15°26' latitude and 75°07' E longitude with an altitude of 678 m above the mean sea level. The Research Station comes under Northern Transitional Zone (Zone-8) of Karnataka which lies between the Western Hilly Zone (Zone 9) and Northern Dry Zone (Zone-3).

3.2 Climatic conditions

The data with regard to rainfall, temperature (maximum and minimum) and relative humidity which were prevailed during the cropping season as recorded at MARS, Dharwad is presented in Table 1 and the rainfall data is depicted in Fig. 1.

The annual rainfall received during 2013 was 740.4 mm distributed in 63 rainy days (Table 1). It was 4 per cent higher than the average rainfall of 63 years (711.1 mm). The rainfall during cropping period (June-November) was 559.4 mm which was distributed in 48 rainy days. The rainfall received in the period of second fortnight of June to first fortnight of July ensured sufficient soil moisture for germination, emergence and early establishment of seedlings for first two (II fortnight of June and I fortnight of July, respectively) dates of sowing. However the crop sown during II fortnight of July did not get sufficient moisture during crop growth period. Even though the maximum rainfall during year was received in the month of July (177.8 mm) followed by September (133.6 mm), the distribution of rainfall was erratic. Hence delayed sown crop (II fortnight of July) suffered from moisture stress during early growth stage, flowering and pod formation stage of the crop. The other parameters namely maximum and minimum temperature and relative humidity did not have any adverse effect on crop growth and yield. The mean maximum temperature during the period of experimentation ranged from 29.0 °C (November) to 25.4 °C (July), while the minimum temperature ranged 15.8 °C (November) to 20.8°C (June). The mean relative humidity varied from 64 per cent in the month of November to 89.0 per cent in the month of July 2013 (Table 1 and Fig. 1).

3.3 Soil and its characteristics

A composite soil sample was drawn to a depth of 30 cm from the experimental area before sowing. The soil was analysed for physical and chemical properties. The soil textural class of the experimental site was clayey (Table 2).

3.4 Previous crop at the experimental site

Groundnut (*kharif*) – fodder sorghum (*rabi*) rotation was practiced during 2012-13 season. The land was fallow during summer 2013 which facilitated for land preparation.

3.5 Experimental details

The details of the experiments with regard to crop, variety, treatment combinations, the design adopted and plot size are given below.

3.5.1 Treatment details

Main plots: Dates of sowing

D ₁	Second fortnight of June
D ₂	First fortnight of July
D ₃	Second fortnight of July

Subplots: planting geometry

S ₁	30 cm row
S ₂	45 cm row
S ₃	60 cm row

Sub sub plots: Genotypes:

G ₁	DC 15
G ₂	C-152

Table 1: Monthly meteorological data during crop growth period (2013) and the average of 63 years (1950-2012) at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad

Month	Rainfall (mm)		Rainy days (2013)	Mean Temperature (°C)				Relative humidity (%)	
	2013	1950-2012		Maximum		Minimum		2013	1950-2012
				2013	1950-2012	2013	1950-2012		
January	0.0	0.8	0	31.2	28.7	14.5	14.1	47	64.7
February	2.2	11.3	0	32.6	31.6	16.8	16.5	51	54.4
March	42.0	1.5	1	35.3	34.9	19.2	19.6	48	63.9
April	10.0	48.7	1	36.9	36.6	20.2	20.1	51	77.7
May	124.6	19.7	6	35.5	35.2	21.8	21.0	61	75.4
June	75.4	105.4	10	28.0	30.2	20.8	21.7	82	86.1
July	177.8	153.1	17	25.4	27.3	20.3	20.9	89	89.1
August	97.2	100.8	10	26.7	27.3	19.9	20.1	85	88.5
September	133.6	107.2	13	26.5	27.9	20.2	20.0	81	86.5
October	75.4	125.3	5	28.8	29.5	19.4	18.6	76	79.2
November	2.2	32.1	0	29.0	28.9	15.8	15.9	64	73.4
December	0.0	5.1	0	28.4	27.8	12.7	13.2	53	68.9
Total	740.4	711.1	63	-	-	-	-	-	-

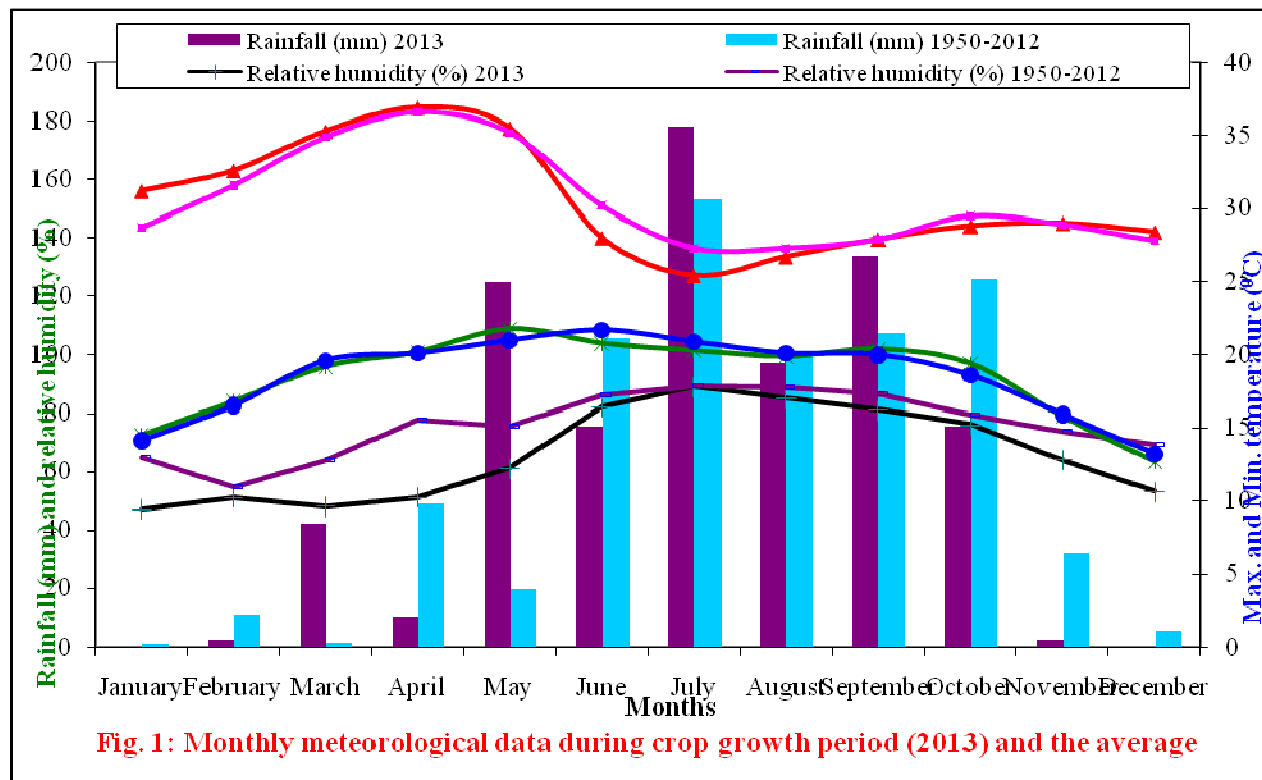


Fig. 1: Monthly meteorological data during crop growth period (2013) and the average of 63 years (1950-2012) at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad

Table 2: Physical and chemical properties of the experimental field

Particulars	Value	Methods employed
1. Physical properties		
Particle size distribution		Hydrometer method (Piper, 1966)
Coarse sand (%)	6	
Fine sand (%)	14	
Silt (%)	28	
Clay (%)	52	
Textural class	Clayey	
2. Chemical properties		
Available N (kg ha ⁻¹)	225.5	Alkaline permanganate method (Subbaiah and Asija, 1956)
Available P ₂ O ₅ (kg ha ⁻¹)	31.9	Olsen's method (Jackson ,1967)
Available K ₂ O (kg ha ⁻¹)	330.5	Flame photometer (Jackson ,1967)
pH (1:2.5, Soil: Water)	7.80	pH mater (Piper, 1966)
Electrical conductivity (dsm ⁻¹)	0.32	EC bridge (Jackson, 1973)

3.5.2 Characteristics of genotypes

Varieties	Salient features
DC 15	It is a newly developed variety under AVT II stage co-ordinated trails. Early maturing, determinate and having duration of 75-85 days. Branching growth habit. Pods are drooping type having a length of 15-18 cm, bold and light creamy coloured seeds. Average yield 10-12 q ha ⁻¹ .
C-152	It is a commonly growing traditional variety of zone 8. Late maturing, indeterminate and having duration of 90-100 days. Less branching type. Length of pods varies from 14-15 cm. Small and light brown coloured seeds. Susceptible to rust and CYMV (cowpea yellow mosaic virus). Average yield 8-10 q ha ⁻¹ .

3.5.3 Design and layout

The experiment was laid out in split- split plot design with three replications. The plan of layout of the experiment is given in Fig. 2 and plate 1.

The other details are as follows.

3.5.3.1 Plot size

Gross plot : 5.4 x 4.0 m

Net Plot : 4.2 x 3.6 m (30 cm row spacing)

3.6 x 3.6 m (45 cm row spacing)

3.0 x 3.6 m (60 cm row spacing)

3.6 Cultural operations

3.6.1 Land preparation

After the harvest of fodder sorghum, the land was ploughed once with tractor mounted mould board plough. Tractor mounted cultivator was passed to break the clods after receipt of summer rains which facilitated for collection of stubbles. Two harrowings were carried out to bring the soil to fine tilth. The plots were marked as per the plan for imposition of treatments. Pre-emergence application of Alachlor carried out to check the weed growth at initial stages of crop.

3.6.2 Fertilizer application

The recommended dose of fertilizers (RDF) was applied to all the treatments at the rate of 25:50:25 of N: P₂O₅: K₂O kg ha⁻¹ in the form of Urea, Diammonium phosphate (DAP) and Murate of potash (MOP) respectively. Entire dose of fertilizers was applied as basal.

3.6.3 Seeds and sowing

Bold and healthy seeds of each variety was sown by dibbling as per the plan. The seeds were sown with a spacing of 30, 45 and 60 cm between rows with same seed rate (30 kg ha⁻¹) to maintain uniform plant population for each treatment. After five days of sowing the gap filling was done and after ten days of sowing, the excess seedlings were thinned out to maintain the optimum plant population.

3.6.4 After care

After thinning one hand weeding was carried out at 15 days after sowing (DAS) followed by one hoeing operation at 30 days after sowing to check the weed growth. The following plant protection operations were carried out to take care of pest and diseases.

Chemical	Dosage	To control
1. Imidacloprid	0.3 ml litre ⁻¹	Vectors of CYMV (sucking insects)
2. Hexaconazole	1 ml litre ⁻¹	Rust disease
3. Ranaxypr	0.1 ml litre ⁻¹	Lepidopteron insects especially pod borer

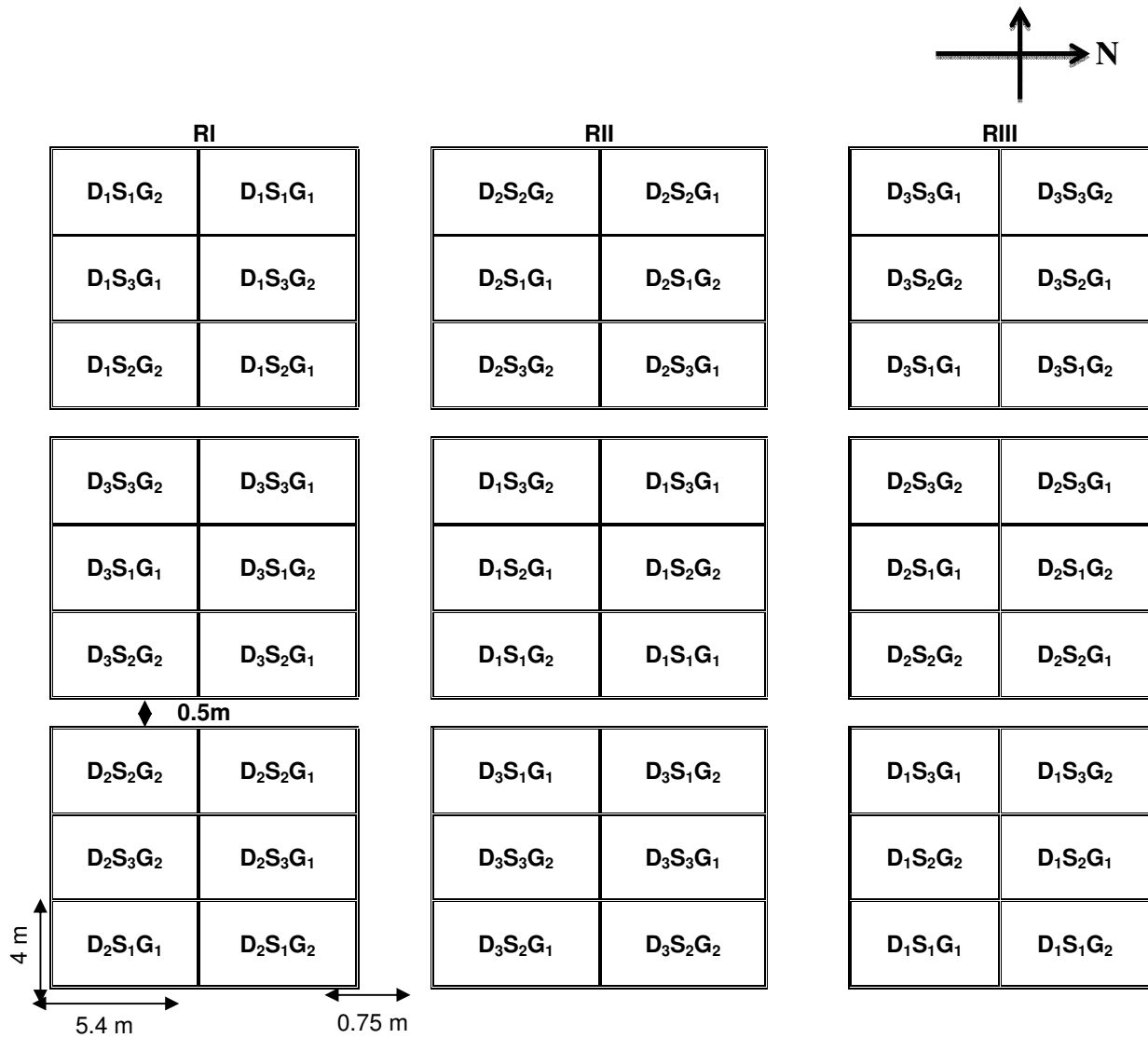


Fig 2: Plan of layout

D = Date of sowing

D₁= Second fort night of June

D₂= First fort night of July

D₃= Second fort night of July

S = Spacing

S₁= 30 cm row

S₂= 45 cm row

S₃= 60 cm row

G = Genotype

G₁= DC 15

G₂= C-152



Plate 1: General view of experimental plot

3.6.5 Harvesting and threshing

Harvesting of cowpea was done when majority of pods in the plots were matured. The pods were picked, air dried and threshed. The seed yield per plot was recorded. After harvest plants were cut at the base and left in the field for drying. The weight of haulm was recorded after complete sun drying.

Date of sowing	Harvesting	
	DC 15	C-152
II Fortnight of June (26-6-2013)	93 days	105 days
I Fortnight of July (13-7-2013)	90 days	99 days
II Fortnight of July (30-7-2013)	85 days	94 days

3.7 Collection of experimental data

For recording various biometric observations, a sample size consisting of five plants from each treatment was selected randomly from net plot area. Observations on growth, morphological, yield and yield parameters were recorded at different stages of plant growth (30, 55 DAS and at Harvest). Observation on quality parameters (seed protein content) was recorded after harvest. The procedures followed to record observations on each parameter are presented in Table 3.

3.8 Statistical analysis of data

The data collected on various characters from the experiment was subjected to statistical analysis as described by Gomez and Gomez (1984). The level of significance used in 'F' and 't' tests was $P = 0.05$ and critical difference values were calculated where 'F' test was found significant.

Table 3: Methods of recording observations on different parameters

I. Growth components		
Sl. No.	Parameters	Procedure followed
1	Plant height (cm)	The plant height from ground surface to the tip of the main stem was measured at 30, 55 DAS (days after sowing) and at harvest. Average height of the randomly selected five plants was recorded.
2	Number of branches plant ⁻¹	The number of primary and secondary branches plant ⁻¹ was counted from five tagged plants and their mean was recorded as number of branches per plant at 30, 55 DAS and at harvest.
3	Canopy spread (cm ² plant ⁻¹)	The canopy spread per plant at 30 and 55 DAS was calculated by multiplying the maximum spread of the plant in two directions perpendicular to each other i.e., N-S and E-W by placing centimeter tape and the observations were recorded for five plants and the average was calculated and expressed in square centimeter.
4	Leaf area (dm ² plant ⁻¹)	<p>Leaf area was recorded by disc method as suggested by Vivekanandan <i>et al.</i> (1972). Fifty leaf discs of known size were taken using a cork borer from randomly selected twenty leaves of five plants. Both discs and remaining leaf blades were oven dried at 65 to 70°C and leaf area was calculated by following the formula at different stages of crop growth (30 and 55 DAS).</p> $LA = \frac{Wa \times A}{Wd}$ <p>Where, LA = Leaf area (dm² plant⁻¹) Wa = Weight of all leaves Wd = Weight of 50 discs A = Area of 50 disc (dm²)</p> <p style="text-align: right;">1) (including 50 discs in g) (g)</p>
5	Leaf area index	<p>It is defined as an assimilatory surface per unit area of land (Sestak <i>et al.</i> 1971). Leaf area index was worked out at 30 and 55 DAS by dividing the leaf area per plant by land area occupied by the plant.</p> $LAI = \frac{\text{Leaf area plant}^{-1} \text{ (dm}^2\text{)}}{\text{Ground area covered (dm}^2\text{)}}$

6	Leaf area duration (days)	<p>Leaf area duration is the integral of LAI over the growth period and was worked out as per the formula given by Power <i>et al.</i> (1967).</p> $\text{LAD} = \frac{L_1 + L_2}{2} \times t_2 - t_1$ <p>Where,</p> <p>L_1 = LAI at time t_1 L_2 = LAI at time t_2 $t_2 - t_1$ = Time interval in days</p>
7	Number of root nodules plant ⁻¹ and dry weight (mg)	The number of root nodules count was taken 35 and 60 DAS in randomly selected five plants. The plants were carefully removed from the soil without damaging the roots, and roots were dipped gently in a bucket containing water to remove the soil and then nodules count was taken, and they were kept in oven to take nodules dry weight.
8	Total dry matter production (g plant ⁻¹)	The five randomly selected plants from sample lines were used to record the dry matter production at different growth stages. The samples were dried at 65°C till they attained constant dry weight. Dry weight was recorded separately at each stage of crop growth. The total dry matter production per plant was expressed in g per plant.

II. Yield parameters		
1	Number of pods plant ⁻¹	The pods of individual plants were counted and average of five plants was recorded as number of pods per plant.
2	Number of seeds pod ⁻¹	The seeds from five representative matured pods were separated and counted. The mean number of seeds per pod was calculated by dividing the number of seeds by the number of pods.
3	Pod length (cm)	Pods of five plants were taken and pod length was measured. Average pod length was calculated.
4	Seed weight per plant (g)	The pods of individual plants were weighed and average of five plants was recorded as weight of pods per plant.
5	Test weight (g)	From seed sample of each treatment, 100 seeds were counted at random and weighed. The 100 seed weight was expressed in grams (g).
6	Seed yield (kg ha ⁻¹)	Seed yield per plot was recorded after threshing and winnowing the seeds from each net plot area. The seed yield ha ⁻¹ was worked out and expressed in kg ha ⁻¹ .
7	Haulm yield (kg ha ⁻¹)	The total biological portion from yield of above ground portion from net plot at harvest was recorded after complete sun drying and haulm yield ha ⁻¹ was worked out by deducting the grain yield.
8	Harvest index (%)	$\text{HI (\%)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$

III Quality parameter		
1	Seed Protein content (%)	Nitrogen content in the grain of cowpea was estimated by Kjeldhal method (Tandan, 1998), and the protein per cent in the grain was calculated by multiplying the nitrogen content with a factor 6.25.
IV Economics		
1	Cost of cultivation (₹ ha ⁻¹)	The prices in rupees of the input that were prevailing at the time of their use were considered for working out of cost of cultivation per hectare treatment wise.
2	Gross return (₹ ha ⁻¹)	Gross return per hectare was calculated by taking into consideration the price of the product that was prevailing in market after harvest.
3	Net return (₹ ha ⁻¹)	The net return per hectare was calculated treatment wise by subtracting the total cost of cultivation from gross returns.
4	Benefit cost ratio (B: C)	Benefit cost ratio (B: C) was worked out treatment wise as follow $B:C = \frac{\text{Gross return (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$

EXPERIMENTAL RESULTS

The results of field experiment conducted to study the “Response of cowpea genotypes to sowing windows and planting geometry, under Northern transitional zone of Karnataka” at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during *kharif* 2013 under rainfed condition are presented in this chapter.

4.1 Growth parameters of cowpea

4.1.1 Plant height (cm)

The data on plant height of cowpea (cm) as influenced by dates of sowing, planting geometry and genotypes and their interactions are presented in Table 4.

At 30 DAS, the plant height differed significantly. Among the dates of sowing the crop sown on second fortnight of June recorded significantly higher plant height (18.8 cm) than first fortnight of July (16.5 cm) and second fortnight of July (12.3 cm) sowings. Among the planting geometry, significantly higher plant height was recorded in 45 and 30 cm row spacing (16.9 and 16.5 cm respectively) compared to 60 cm (14.2 cm) and 30 cm row spacing was on par with 45 cm. No significant difference was observed between the genotypes. None of the interaction effects were significantly differed except dates of sowing and planting geometry. The interaction D_1S_2 (second fortnight of June and 45 cm row spacing) recorded significantly higher plant height (20.9 cm) over others. The lower plant height was recorded in the interaction D_3S_3 (10.8 cm) compared to other interactions.

At 55 DAS, among the dates of sowing, the second fortnight of June recorded significantly higher plant height (60.1 cm) compared to other sowing dates. First fortnight of July (57.1 cm) was on par with second fortnight July (55.8 cm). Significantly higher plant height was recorded in 45 cm row spacing (61.5 cm) than the 30 (59.8 cm) and 60 cm (51.7 cm). Significantly higher plant height was recorded in genotype DC 15 (58.9 cm) over C-152 (56.4 cm). None of the interaction effects were significant except dates of sowing and planting geometry. The interaction D_1S_2 (second fortnight of June and 45 cm row) recorded significantly higher plant height (64.3 cm) as compared to others where as the interaction D_2S_2 (61.5 cm) (first fortnight of July and 45 cm row), D_2S_1 (60.7 cm) (first fortnight of July and 30 cm row) and D_1S_1 (60.1 cm) (second fortnight of June and 30 cm row) were on par with each other. However, significantly lower plant height was recorded in D_2S_3 (49.0 cm) (first fortnight of July and 60 cm row).

At harvest, the plant height differed significantly. Among the dates of sowing, the crop sown on second fortnight June (95.7 cm) recorded significantly higher plant height over second fortnight July (83.9 cm) and it was on par with first fortnight July (89.4 cm) where as first and second fortnight of July were on par with each other. Among the planting geometry, significantly higher plant height was recorded in 45 cm row spacing (96.2 cm) over the 60 cm row (79.7 cm) and it was on par with 30 cm row (93.1 cm). Similarly significant difference was observed in plant height between the genotypes. Significantly higher plant height was recorded in DC 15 (91.6 cm) than C-152 (87.8 cm). None of the interaction effects were significant.

4.1.2 Number of primary branches plant⁻¹

The number of branches plant⁻¹ differed significantly at 30 DAS. Among the dates of sowing the crop sown on second fortnight of June recorded significantly higher number of primary branches plant⁻¹ (3.3) than first fortnight of July (2.7) and second fortnight of July (2.3). Among the planting geometry, significantly higher number of branches plant⁻¹ was recorded in 45 cm row (3.2) compared to 60 cm (2.2) and it was on par with 30 cm row (3.0). There is no significant difference was observed between the genotypes. None of the interaction effects were significant (Table 5).

At 55 DAS, among the dates of sowings, second fortnight of June recorded significantly higher number of branches plant⁻¹ (8.0) and it was on par with first fortnight of July (7.8) as compared to second fortnight of July (6.5). Significantly higher number of branches plant⁻¹ was recorded in 45 cm row spacing (8.00) over 60 cm row (6.48) and it was on par with 30 cm row (7.8). However significant difference was observed in number of branches plant⁻¹ between the genotypes. Significantly higher number of branches was recorded in DC 15 (7.7) than C-152 (7.1). None of the interaction effects were significant except dates of sowing and planting geometry. The interaction D_1S_2 (second fortnight of June and 45cm row) recorded significantly higher number of branches plant⁻¹ (8.9) as compared to other treatment combinations. However the interaction D_2S_2 (8.5), D_2S_1 (8.1) and D_1S_1 (8.0) were on par with each other. Lower number of branches plant⁻¹ was recorded in D_3S_3 (second fortnight of July and 60 cm row) (5.6) as compared to other treatment combinations (Table 5).

Table 4: Plant height (cm) of cowpea genotypes as influenced by sowing windows and planting geometry

Treatment		Row spacing (S)											
		30 DAS				55 DAS				At harvest			
Date of sowing (D)	Genotypes	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean
D ₁ : II FN of June	G ₁	19.3	21.2	16.4	19.0	61.6	65.4	57.5	61.5	97.5	105.4	90.7	97.9
	G ₂	18.9	20.6	16.4	18.6	58.7	63.2	54.1	58.7	93.9	101.3	85.7	93.6
	Mean	19.1	20.9	16.4	18.8	60.1	64.3	55.8	60.1	95.7	103.4	88.2	95.7
D ₂ : I FN of July	G ₁	17.0	17.5	15.2	16.6	61.9	62.7	49.7	58.1	96.3	97.6	78.9	90.9
	G ₂	16.8	17.1	15.4	16.4	59.5	60.3	48.4	56.0	93.6	93.4	76.6	87.9
	Mean	16.9	17.3	15.3	16.5	60.7	61.5	49.0	57.1	94.9	95.5	77.8	89.4
D ₃ : II FN of July	G ₁	13.8	12.5	10.9	12.4	60.2	59.5	51.8	57.2	91.3	91.4	75.1	85.9
	G ₂	13.5	12.3	10.7	12.1	56.9	57.9	48.8	54.5	86.3	87.9	71.3	81.8
	Mean	13.6	12.4	10.8	12.3	58.6	58.7	50.3	55.8	88.8	89.7	73.2	83.9
Mean of G ₁		16.7	17.1	14.2	15.9	61.2	62.5	53.0	58.9	95.0	98.1	81.6	91.6
Mean of G ₂		16.4	16.6	14.1	15.7	58.4	60.4	50.4	56.4	91.2	94.2	77.9	87.8
Mean		16.5	16.8	14.2		59.8	61.5	51.7		93.1	96.2	79.7	
Sources		S.Em ±		CD (P = 0.05)		S.Em±		CD (P = 0.05)		S.Em ±		CD (P = 0.05)	
Date of sowing (D)		0.19		0.73		0.43		1.68		1.92		7.55	
Row Spacing (S)		0.19		0.58		0.34		1.06		1.25		3.85	
Genotype (G)		0.10		NS		0.23		0.69		0.27		0.81	
D X S		0.32		0.10		0.60		1.84		2.16		NS	
D X G		0.18		NS		0.40		NS		0.47		NS	
S X G		0.18		NS		0.40		NS		0.47		NS	
D X S X G		0.30		NS		0.70		NS		0.82		NS	

D = Date of sowing

D₁= Second fortnight of June (26th June)

D₂= First fortnight of July (13th July)

D₃= Second fortnight of July (30th July)

S= Row Spacing

S₁= 30 cm

S₂= 45 cm

S₃= 60 cm

G = Genotypes

G₁= DC-15

G₂= C-152

DAS= Days after sowing

FN = Fortnight

NS= Non Significant

Table 5: Number of primary branches plant⁻¹ of cowpea genotypes as influenced by sowing windows and planting geometry

Treatment		Row spacing (S)											
		30 DAS				55 DAS				At harvest			
Date of sowing (D)	Genotypes (G)	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean
D ₁ : II FN of June	G ₁	3.4	3.9	2.9	3.4	8.2	9.0	7.5	8.3	10.1	10.6	9.0	9.9
	G ₂	3.4	3.7	2.7	3.3	7.8	8.8	6.4	7.7	9.7	10.2	8.8	9.6
	Mean	3.4	3.8	2.8	3.3	8.0	8.9	7.0	8.0	9.9	10.4	8.9	9.7
D ₂ : I FN of July	G ₁	2.7	3.1	2.2	2.7	8.3	8.8	7.4	8.2	10.0	10.1	8.8	9.6
	G ₂	2.7	3.1	2.1	2.6	8.0	8.2	6.3	7.5	9.7	10.0	8.2	9.3
	Mean	2.7	3.1	2.2	2.7	8.1	8.5	6.9	7.8	9.9	10.1	8.5	9.5
D ₃ : II FN of July	G ₁	2.7	2.6	1.6	2.3	7.2	7.0	5.8	6.7	8.7	8.5	7.3	8.2
	G ₂	2.9	2.5	1.5	2.3	7.1	6.1	5.4	6.2	8.6	7.6	6.9	7.7
	Mean	2.8	2.6	1.6	2.3	7.2	6.6	5.6	6.5	8.7	8.1	7.1	8.0
Mean of G ₁		2.9	3.2	2.2	2.8	7.9	8.3	6.9	7.7	9.6	9.8	8.4	9.3
Mean of G ₂		3.0	3.1	2.1	2.7	7.7	7.7	6.0	7.1	9.3	9.3	8.0	8.9
Mean		3.0	3.2	2.2		7.8	8.0	6.5		9.5	9.5	8.2	
Sources		S.Em ±		CD (P = 0.05)		S.Em±		CD (P = 0.05)		S.Em ±		CD (P = 0.05)	
Date of sowing (D)		0.10		0.36		0.12		0.46		0.12		0.47	
Row Spacing (S)		0.10		0.31		0.07		0.24		0.08		0.24	
Genotype (G)		0.03		NS		0.07		0.21		0.06		0.19	
D X S		0.17		NS		0.13		0.40		0.14		0.42	
D X G		0.05		NS		0.12		NS		0.11		NS	
S X G		0.05		NS		0.12		NS		0.11		NS	
D X S X G		0.08		NS		0.21		NS		0.19		NS	

D = Date of sowing

D₁= Second fortnight of June (26th June)

D₂= First fortnight of July (13th July)

D₃= Second fortnight of July (30th July)

S= Row Spacing

S₁= 30 cm

S₂= 45 cm

S₃= 60 cm

G = Genotypes

G₁= DC-15

G₂= C-152

DAS= Days after sowing

FN = Fortnight

NS= Non Significant

Table 6: Number of Secondary branches plant⁻¹ of cowpea genotypes as influenced by sowing windows and planting geometry

Treatment		Row spacing (S)							
		55 DAS				At harvest			
Date of sowing (D)	Genotypes (G)	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean
D ₁ : II FN of June	G ₁	1.7	2.2	0.8	1.5	2.3	2.4	1.9	2.2
	G ₂	1.6	2.1	0.8	1.5	2.3	2.2	1.8	2.1
	Mean	1.6	2.2	0.8	1.5	2.3	2.3	1.9	2.2
D ₂ : I FN of July	G ₁	1.5	1.3	0.8	1.2	2.0	2.0	1.6	1.9
	G ₂	1.3	1.1	0.8	1.1	1.9	1.9	1.3	1.7
	Mean	1.4	1.2	0.8	1.2	2.0	2.0	1.5	1.8
D ₃ : II FN of July	G ₁	1.1	1.0	0.6	0.9	1.2	1.7	1.0	1.3
	G ₂	1.1	1.0	0.6	0.9	1.2	1.4	0.9	1.2
	Mean	1.1	1.0	0.6	0.9	1.2	1.6	1.0	1.2
Mean of G ₁		1.4	1.5	0.7	1.2	1.8	2.0	1.5	1.8
Mean of G ₂		1.3	1.4	0.7	1.2	1.8	1.8	1.4	1.7
Mean		1.4	1.5	0.7		1.8	1.9	1.4	
Sources		S.Em±			CD (P = 0.05)		S.Em ±		CD (P = 0.05)
Date of sowing (D)		0.05			0.18		0.09		0.35
Row Spacing (S)		0.08			0.25		0.03		0.10
Genotype (G)		0.03			NS		0.03		0.09
D X S		0.14			0.42		0.06		0.17
D X G		0.05			NS		0.05		NS
S X G		0.05			NS		0.05		NS
D X S X G		0.09			NS		0.09		NS

D = Date of sowing

D₁= Second fortnight of June (26th June)

D₂= First fortnight of July (13th July)

D₃= Second fortnight of July (30th July)

S= Row Spacing

S₁= 30 cm

S₂= 45 cm

S₃= 60 cm

G = Genotypes

G₁= DC-15

G₂= C-152

DAS= Days after sowing

FN = Fortnight

NS= Non Significant

Table 7: Canopy spread (cm² plant⁻¹) of cowpea genotypes as influenced by sowing windows and planting geometry

Treatment		Row spacing (S)							
		30 DAS				55 DAS			
Date of sowing (D)	Genotypes (G)	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean
D ₁ : II FN of June	G ₁	645.4	725.7	487.4	619.5	2211.6	2562.8	1716.5	2163.6
	G ₂	619.0	707.9	496.0	607.6	2068.2	2456.1	1704.9	2076.4
	Mean	632.2	716.8	491.7	613.6	2139.9	2509.5	1710.7	2120.0
D ₂ : I FN of July	G ₁	516.7	573.2	494.1	528.0	2074.7	2472.1	1393.5	1980.1
	G ₂	513.9	543.3	499.9	519.0	1968.7	2321.7	1269.7	1853.4
	Mean	515.3	558.3	497.0	523.5	2021.7	2396.9	1331.6	1916.7
D ₃ : II FN of July	G ₁	546.8	554.1	497.9	532.9	1389.9	1695.9	911.9	1332.5
	G ₂	595.4	562.7	493.6	550.7	1291.8	1463.4	823.1	1192.8
	Mean	571.1	558.4	495.7	541.7	1340.8	1579.6	867.5	1262.7
Mean of G ₁		569.6	617.7	493.1	560.1	1892.0	2243.6	1340.6	1825.4
Mean of G ₂		576.1	604.7	496.5	559.1	1776.2	2080.4	1265.9	1707.5
Mean		572.9	611.2	494.8		1834.1	2162.0	1303.3	
Sources		S.Em ±			CD (P = 0.05)		S.Em±		CD (P = 0.05)
Date of sowing (D)		13.93			54.71		125.45		492.57
Row Spacing (S)		16.93			52.17		89.86		276.87
Genotype (G)		7.57			NS		21.56		64.05
D X S		29.33			NS		155.64		NS
D X G		13.11			NS		37.34		NS
S X G		13.11			NS		37.34		NS
D X S X G		22.71			NS		64.67		NS

D = Date of sowing

D₁= Second fortnight of June (26th June)

D₂= First fortnight of July (13th July)

D₃= Second fortnight of July (30th July)

S= Row Spacing

S₁= 30 cm

S₂= 45 cm

S₃= 60 cm

G = Genotypes

G₁= DC-15

G₂= C-152

DAS= Days after sowing

FN = Fortnight

NS= Non Significant

At harvest, number of branches plant⁻¹ differed significantly. Among the dates of sowing, the crop sown second fortnight of June (9.7) recorded significantly higher number of branches plant⁻¹ compared to second fortnight of July (8.0) and it was on par with first fortnight of July (9.5). Significantly higher numbers of branches were recorded in 30 and 45 cm row spacing (9.5 each) over 60 cm row (8.2). Genotypes differed significantly for number of branches. DC 15 recorded significantly higher number of branches (9.3) than C-152 (8.9). None of the interaction effects were significant except dates of sowing and planting geometry. The interaction D₁S₂ (second fortnight of June and 45 cm row) recorded significantly higher number of branches plant⁻¹ (10.4) as compared to other treatment combinations, however it was on par with D₂S₂ (10.1), D₂S₁ (9.9) and D₁S₁ (9.9) treatments. The least number of branches plant⁻¹ (7.1) were recorded in D₃S₃ (second fortnight of July and 60 cm row) as compared to other treatment combinations (Table 5).

4.1.3 Number of secondary branches plant⁻¹

The data on number of secondary branches plant⁻¹ of cowpea genotypes as influenced by dates of sowing and planting geometry and their interactions are presented in Table 6.

At 55 DAS, among the dates of sowing, the second fortnight of June recorded significantly higher number of secondary branches plant⁻¹ (1.5) over rest of the sowing dates *i.e.* first fortnight of July (1.2) and second fortnight of July (0.9). Significantly higher number of secondary branches plant⁻¹ was recorded in 45 cm row spacing (1.5) compared to 60 cm row (0.7) and it was on par with 30 cm row (1.4). There was no significant difference between the genotypes for number of secondary branches plant⁻¹. None of the interaction effects were significant except dates of sowing and planting geometry. The interaction D₁S₂ (second fortnight of June and 45 cm row) recorded significantly higher number of secondary branches (2.2) than other interactions. However, the least number of secondary branches plant⁻¹ were recorded in D₃S₃ (0.6) (second fortnight of July and 60 cm row) as compared to other treatment combinations.

At harvest, number of secondary branches plant⁻¹ differed significantly among the dates of sowing. The crop sown on second fortnight of June (2.2) recorded significantly higher number of secondary branches plant⁻¹ over first fortnight of July (1.8) and second fortnight of July (1.2). Among planting geometry, significantly higher number of secondary branches plant⁻¹ were recorded in 45 cm row spacing (1.9) compared to 30 cm row (1.8) and 60 cm row (1.4). Between the genotypes, DC 15 recorded significantly higher number of secondary branches (1.8) plant⁻¹ than C-152 (1.7). None of the interaction effects were significant except dates of sowing and planting geometry. The interaction D₁S₁ (second fortnight of June and 30 cm row) and D₁S₂ (second fortnight of June and 45 cm row) recorded equal number of secondary branches (2.3 and 2.3 respectively), and were significantly higher as compared to other treatment combinations. However, the lower number of secondary branches was recorded in D₃S₃ (1.0) compared to other treatment combinations.

4.1.4 Canopy spread (cm² plant⁻¹)

The spread of the canopy increased continuously from 30 to 55 DAS. Canopy spread differed significantly for different sowing dates. At 30 and 55 DAS higher canopy spread was recorded in June second fortnight sown crop (613.6 and 2120.0 cm² respectively) as compared to July first fortnight (523.5 and 1916.7 cm² respectively) and July second fortnight (541.7 and 1262.7 cm² respectively) and there was no significant difference between D₂ and D₃ at 30 DAS and, D₁ and D₂ at 55 DAS (Table 7).

Canopy spread significantly differed due to planting geometry. Higher canopy spread was recorded with 45 cm row spacing at 30 and 55 DAS (611.1 and 2162.0 cm² respectively) when compared to 30 cm row (572.9 and 1834.1 cm² respectively) and 60 cm row (494.8 and 1303.3 cm² respectively). However 45 cm row was on par with 30 cm row at 30 DAS (Table 7).

Genotypes differed significantly with respect to canopy spread. At 55 DAS significantly higher canopy spread was recorded in DC 15 (1825.4 cm²) as compared to C-152 (1707.5 cm²). No significant difference was observed between genotypes at 30 DAS for canopy spread (Table 7).

4.1.5 Leaf area (dm² plant⁻¹)

The data on leaf area (LA) of cowpea genotypes as influenced by dates of sowing and planting geometry and their interactions are presented in Table 8.

At 30 DAS, the leaf area differed significantly. Among the dates of sowing the crop sown on second fortnight of June recorded significantly higher LA (33.9 dm² plant⁻¹) over first fortnight of July

(27.1 dm² plant⁻¹) and second fortnight of July (24.3 dm² plant⁻¹) where as D₃ was on par with D₂. Similarly, significantly higher LA was recorded in 45 cm row spacing (30.1 dm² plant⁻¹) compared to 60 cm row (26.3 dm² plant⁻¹) however it was on par with 30 cm row (28.9 dm² plant⁻¹). No significant difference was observed between genotypes. None of the interaction effects were significant.

At 55 DAS among the dates of sowing, the second fortnight of June recorded significantly higher LA (106.1 dm² plant⁻¹) compared to second fortnight of July (95.1 dm² plant⁻¹) and it was on par with first fortnight of July (99.7 dm² plant⁻¹). However there was no significant difference between D₂ and D₃. Significantly higher LA was recorded in 45 cm row spacing (105.1 dm² plant⁻¹) over 30 cm row (100.5 dm² plant⁻¹) and 60 cm row (95.1 dm² plant⁻¹). Genotypes differed significantly with respect to LA. DC 15 recorded significantly higher LA (101.7 dm² plant⁻¹) than C-152 (98.8 dm² plant⁻¹). None of the interaction effects were significant except dates of sowing and planting geometry. The interaction D₁S₂ (second fortnight of June and 45 cm row) recorded significantly higher LA (114.1 dm² plant⁻¹) as compared to other treatment combinations. The lower LA was recorded in D₃S₃ (90.2 dm² plant⁻¹).

At harvest, LA differed significantly. Among the dates of sowing, the crop sown on second fortnight of June (59.9 dm² plant⁻¹) recorded significantly higher LA over first fortnight of July (53.5 dm² plant⁻¹) and second fortnight of July (50.2 dm² plant⁻¹) however D₃ was on par with D₂. Among the planting geometry, significantly higher LA was recorded in 45 cm row spacing (58.6 dm² plant⁻¹) over 60 cm row (50.2 dm² plant⁻¹) followed by 30 cm row (54.8 dm² plant⁻¹). LA was significantly superior in DC 15 (55.9 dm² plant⁻¹) than C-152 (53.2 dm² plant⁻¹). None of the interaction effects were significantly differed.

4.1.6 Leaf area index (LAI)

The leaf area index differed significantly at 30 DAS. Among the dates of sowing the crop sown on second fortnight of June recorded significantly higher LAI (1.13) over first fortnight of July (0.90) and second fortnight of July (0.81) and there was no significant difference between D₂ and D₃. Similarly, planting geometry differed significantly. Higher LAI was recorded in 45 cm row spacing (1.00) over 60 cm row (0.88). However there is no significant difference between 45 and 30 cm row (0.96). No significant difference was observed in LAI between the genotypes. None of the interaction effects were significant (Table 9).

At 55 DAS among the dates of sowing, the second fortnight of June recorded significantly higher LAI (3.54) as compared to second fortnight of July (3.17) and which is on par with first fortnight of July (3.32) and there is no significant difference between D₂ and D₃. Significantly higher LAI was recorded in 45 cm row spacing (3.50) over 30 (3.35) and 60 cm row (3.17). Genotypes differed significantly. Higher LAI was observed in DC 15 (3.39) over C-152 (3.29). None of the interaction effects were significant except dates of sowing and planting geometry. The interaction D₁S₂ recorded significantly higher LAI (3.80) as compared to others. The lower LAI was recorded in D₃S₃ (3.01) (Table 9).

At harvest, LAI differed significantly among the dates of sowing, the crop sown on second fortnight of June recorded significantly higher LAI (2.00) over first fortnight of July (1.78) and second fortnight of July (1.67) however D₃ was on par with D₂. Among the planting geometry, significantly higher LAI was recorded in 45 cm row spacing (1.95) over 60 cm row (1.67) and it was on par with 30 cm row (1.78). LAI was significantly superior in DC 15 (1.86) as compared to C-152 (1.77). None of the interaction effects were significant (Table 9).

4.1.7 Leaf area duration (days)

The data on leaf area duration (LAD) of cowpea genotypes as influenced by dates of sowing and planting geometry and their interactions are presented in Table 10.

At 30-55 DAS, LAD differed significantly. Among the dates of sowing, the crop sown on second fortnight of June recorded significantly higher LAD (58 days) over first fortnight of July (53 days) and second fortnight of July (50 days) where as there was no significant difference between D₂ and D₃. Significantly higher LAD was recorded in 45 cm row spacing (56 days) over 30 cm row (54 days) and 60 cm row (51 days). Genotypes differed significantly with respect to LAD. Higher LAD was recorded in DC 15 (54.41 days) than C-152 (52.81 days). None of the interaction effects were significant except dates of sowing and planting geometry. The interaction D₁S₂ recorded significantly higher LAD (63 days) as compared to other interactions. However, the LAD was least in D₃S₃ (47 days).

Table 8: Leaf area (dm² plant⁻¹) of cowpea genotypes as influenced by sowing windows and planting geometry

Treatment		Row spacing (S)												
		30 DAS				55 DAS				At harvest				
Date of sowing (D)	Genotypes	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean	
D ₁ : II FN of June	G ₁	35.0	38.2	31.2	34.8	108.2	116.4	98.9	107.9	62.0	66.5	53.6	60.7	
	G ₂	32.7	35.8	30.3	32.9	104.2	111.7	97.2	104.4	59.2	64.8	53.4	59.1	
	Mean	33.8	37.0	30.7	33.9	106.2	114.1	98.1	106.1	60.6	65.6	53.5	59.9	
D ₂ : I FN of July	G ₁	28.1	28.9	25.0	27.4	99.1	104.5	98.0	100.6	57.0	59.2	49.5	55.2	
	G ₂	26.4	28.2	26.1	26.9	100.7	99.2	96.2	98.7	54.8	51.4	49.2	51.8	
	Mean	27.3	28.6	25.6	27.1	99.9	101.9	97.1	99.6	55.9	55.3	49.4	53.5	
D ₃ : II FN of July	G ₁	26.7	25.3	21.6	24.5	98.5	101.4	90.4	96.8	49.3	57.2	48.7	51.7	
	G ₂	24.4	24.3	23.3	24.0	92.6	97.5	89.9	93.3	46.6	52.4	46.7	48.6	
	Mean	25.6	24.8	22.5	24.3	95.6	99.4	90.2	95.1	48.0	54.8	47.7	50.2	
Mean of G ₁		29.9	30.8	25.9	28.9	101.9	107.5	95.8	101.7	56.1	60.96	50.6	55.9	
Mean of G ₂		27.8	29.4	26.6	27.9	99.15	102.8	94.5	98.8	53.6	56.17	49.8	53.2	
Mean		28.9	30.1	26.3		100.5	105.2	95.1		54.8	58.58	50.2		
Sources		S.Em ±			CD (P = 0.05)		S.Em±		CD (P = 0.05)		S.Em ±		CD (P = 0.05)	
Date of sowing (D)		1.26			4.93		1.96		7.71		1.41		5.52	
Row Spacing (S)		0.73			2.25		0.75		2.30		1.14		3.51	
Genotype (G)		0.68			NS		0.63		1.87		0.46		1.36	
D X S		1.27			NS		1.29		3.98		1.97		NS	
D X G		1.17			NS		1.09		NS		0.79		NS	
S X G		1.17			NS		1.09		NS		0.79		NS	
D X S X G		2.03			NS		1.88		NS		1.37		NS	

D = Date of sowing

D₁= Second fortnight of June (26th June)

D₂= First fortnight of July (13th July)

D₃= Second fortnight of July (30th July)

S= Row Spacing

S₁= 30 cm

S₂= 45 cm

S₃= 60 cm

G = Genotypes

G₁= DC-15

G₂= C-152

DAS= Days after sowing

FN = Fortnight

NS= Non Significant

Table 9: Leaf area index of cowpea genotypes as influenced by sowing windows and planting geometry

Treatment		Row spacing (S)											
		30 DAS				55 DAS				At harvest			
Date of sowing (D)	Genotypes(G)	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean
D ₁ : II FN of June	G ₁	1.17	1.27	1.04	1.16	3.61	3.88	3.30	3.60	2.07	2.22	1.78	2.02
	G ₂	1.09	1.19	1.01	1.10	3.47	3.72	3.24	3.48	1.97	2.16	1.78	1.97
	Mean	1.13	1.23	1.03	1.13	3.54	3.80	3.27	3.54	2.02	2.19	1.78	2.00
D ₂ : I FN of July	G ₁	0.93	0.96	0.83	0.91	3.30	3.48	3.27	3.35	1.90	1.97	1.65	1.84
	G ₂	0.88	0.94	0.87	0.90	3.36	3.30	3.21	3.29	1.83	1.71	1.64	1.73
	Mean	0.91	0.95	0.85	0.90	3.33	3.39	3.24	3.32	1.86	1.84	1.65	1.78
D ₃ : II FN of July	G ₁	0.89	0.84	0.72	0.82	3.28	3.38	3.01	3.23	1.65	1.91	1.62	1.73
	G ₂	0.81	0.81	0.78	0.80	3.08	3.25	3.00	3.11	1.55	1.75	1.56	1.62
	Mean	0.85	0.83	0.75	0.81	3.18	3.31	3.01	3.17	1.60	1.83	1.59	1.67
Mean of G ₁		1.00	1.03	0.86	0.96	3.40	3.58	3.19	3.39	1.87	2.03	1.69	1.86
Mean of G ₂		0.93	0.98	0.89	0.93	3.30	3.42	3.15	3.29	1.78	1.87	1.66	1.77
Mean		0.96	1.00	0.88		3.35	3.50	3.17		1.83	1.95	1.67	
Sources		S.Em ±		CD (P = 0.05)		S.Em±		CD (P = 0.05)		S.Em ±		CD (P = 0.05)	
Date of sowing (D)		0.04		0.17		0.07		0.26		0.05		0.18	
Row Spacing (S)		0.02		0.07		0.02		0.08		0.04		0.12	
Genotype (G)		0.02		NS		0.02		0.06		0.02		0.05	
D X S		0.04		NS		0.04		0.13		0.07		NS	
D X G		0.04		NS		0.04		NS		0.03		NS	
S X G		0.04		NS		0.04		NS		0.03		NS	
D X S X G		0.07		NS		0.06		NS		0.05		NS	

D = Date of sowing

D₁= Second fortnight of June (26th June)

D₂= First fortnight of July (13th July)

D₃= Second fortnight of July (30th July)

S= Row Spacing

S₁= 30 cm

S₂= 45 cm

S₃= 60 cm

G = Genotypes

G₁= DC-15

G₂= C-152

DAS= Days after sowing

FN = Fortnight

NS= Non Significant

Table 10: Leaf area duration (days) of cowpea genotypes as influenced by sowing windows and planting geometry

Treatment		Row spacing (S)							
		30-55 DAS				55 DAS-At harvest			
Date of sowing (D)	Genotypes (G)	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean
D ₁ : II FN of June	G ₁	59.7	64.4	54.2	59.4	85.2	91.5	76.3	84.3
	G ₂	57.1	61.5	53.1	57.2	81.7	88.3	75.3	81.7
	Mean	58.4	62.9	53.7	58.3	83.4	89.9	75.8	83.0
D ₂ : I FN of July	G ₁	52.9	55.6	51.3	53.3	78.0	81.8	73.9	77.9
	G ₂	53.0	53.1	51.0	52.4	77.8	75.3	72.8	75.3
	Mean	53.0	54.3	51.2	52.8	77.9	78.5	73.3	76.6
D ₃ : II FN of July	G ₁	52.1	52.8	46.7	50.5	74.0	79.3	69.6	74.3
	G ₂	48.7	50.7	47.2	48.9	69.6	74.9	68.3	70.9
	Mean	50.4	51.8	46.9	49.7	71.8	77.1	68.9	72.6
Mean of G ₁		54.9	57.6	50.7	54.4	79.0	84.2	73.2	78.8
Mean of G ₂		52.9	55.1	50.4	52.8	76.3	79.5	72.1	76.0
Mean		53.9	56.3	50.6		77.7	81.8	72.7	
Sources		S.Em ±		CD (P = 0.05)		S.Em±		CD (P = 0.05)	
Date of sowing (D)		1.26		4.93		1.26		4.96	
Row Spacing (S)		0.40		1.24		0.73		2.26	
Genotype (G)		0.44		1.31		0.39		1.16	
D X S		0.70		2.15		1.27		3.91	
D X G		0.76		NS		0.68		NS	
S X G		0.76		NS		0.68		NS	
D X S X G		1.32		NS		1.17		NS	

D = Date of sowing

D₁= Second fortnight of June (26th June)

D₂= First fortnight of July (13th July)

D₃= Second fortnight of July (30th July)

S= Row Spacing

S₁= 30 cm

S₂= 45 cm

S₃= 60 cm

G = Genotypes

G₁= DC-15

G₂= C-152

DAS= Days after sowing

FN = Fortnight

NS= Non Significant

Table 11: Number of effective nodules plant⁻¹ of cowpea genotypes as influenced by sowing windows and planting geometry

Treatment		Row spacing (S)											
		35 DAS				60 DAS				At harvest			
Date of sowing (D)	Genotypes (G)	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean
D ₁ : II FN of June	G ₁	7.83	7.90	6.67	7.47	33.67	35.73	27.53	32.31	6.98	7.42	6.17	6.86
	G ₂	7.33	7.67	6.93	7.31	32.47	34.27	26.00	30.91	7.04	7.20	5.71	6.65
	Mean	7.58	7.78	6.80	7.39	33.07	35.00	26.77	31.61	7.01	7.31	5.94	6.75
D ₂ : I FN of July	G ₁	6.33	8.00	5.67	6.67	28.67	33.87	20.20	27.58	6.11	6.79	5.47	6.12
	G ₂	6.33	7.67	5.33	6.44	27.13	29.67	21.67	26.16	6.10	6.41	5.36	5.96
	Mean	6.33	7.83	5.50	6.56	27.90	31.77	20.93	26.87	6.11	6.60	5.41	6.04
D ₃ : II FN of July	G ₁	6.33	7.33	5.33	6.33	27.53	31.93	22.40	27.29	5.16	5.83	4.67	5.22
	G ₂	6.00	6.67	5.33	6.00	25.27	27.97	21.13	24.79	5.00	5.32	4.43	4.91
	Mean	6.17	7.00	5.33	6.17	26.40	29.95	21.77	26.04	5.08	5.58	4.55	5.07
Mean of G ₁		6.83	7.74	5.89	6.82	29.96	33.84	23.38	29.06	6.08	6.68	5.44	6.07
Mean of G ₂		6.56	7.33	5.87	6.59	28.29	30.63	22.93	27.29	6.05	6.31	5.17	5.84
Mean		6.69	7.54	5.88		29.12	32.24	23.16		6.06	6.49	5.30	
Sources		S.Em ±		CD (P = 0.05)		S.Em±		CD (P = 0.05)		S.Em ±		CD (P = 0.05)	
Date of sowing (D)		0.06		0.24		0.83		3.27		0.17		0.68	
Row Spacing (S)		0.14		0.44		0.94		2.89		0.15		0.47	
Genotype (G)		0.11		NS		0.42		1.25		0.06		0.17	
D X S		0.25		NS		1.62		NS		0.26		NS	
D X G		0.19		NS		0.73		NS		0.10		NS	
S X G		0.19		NS		0.73		NS		0.10		NS	
D X S X G		0.34		NS		1.26		NS		0.17		NS	

D = Date of sowing
D₁= Second fortnight of June (26th June)
D₂= First fortnight of July (13th July)
D₃= Second fortnight of July (30th July)

S= Row Spacing
S₁= 30 cm
S₂= 45 cm
S₃= 60 cm

G = Genotypes
G₁= DC-15
G₂= C-152

DAS= Days after sowing
FN = Fortnight
NS= Non Significant

Table 12: Nodules dry weight (mg plant⁻¹) of cowpea genotypes as influenced by sowing windows and planting geometry

Treatment		Row spacing (S)												
		35 DAS				60 DAS				At harvest				
Date of sowing (D)	Genotypes	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean	
D₁ : II FN of June	G ₁	33.70	34.07	31.27	32.67	192.67	197.73	167.20	185.87	35.00	36.80	31.53	34.44	
	G ₂	32.73	33.67	30.67	32.49	188.00	196.00	160.33	181.44	35.00	35.90	29.63	33.51	
	Mean	32.90	33.87	30.97	32.58	190.33	196.87	163.77	183.66	35.00	36.35	30.58	33.98	
D₂ : I FN of July	G ₁	31.83	32.67	29.33	31.13	172.07	194.07	135.00	167.04	31.43	34.20	28.83	31.49	
	G ₂	31.40	32.67	29.00	31.17	165.33	175.80	140.87	160.67	31.27	32.83	28.17	30.76	
	Mean	31.62	32.67	29.17	31.15	168.70	184.93	137.93	163.86	31.35	33.52	28.50	31.12	
D₃ : II FN of July	G ₁	30.53	31.63	29.03	30.40	167.00	177.67	144.33	163.00	27.33	30.17	25.47	27.66	
	G ₂	30.40	30.83	28.87	30.03	157.20	168.00	138.53	154.58	26.83	28.03	24.13	26.33	
	Mean	30.47	31.23	28.95	30.22	162.10	172.83	141.43	158.79	27.08	29.10	24.80	26.99	
Mean of G ₁		31.67	32.66	29.88	31.40	177.24	189.82	148.84	171.97	31.26	33.72	28.61	31.20	
Mean of G ₂		31.66	32.52	29.51	31.23	170.18	179.93	146.58	165.56	31.03	32.26	27.31	30.20	
Mean		31.66	32.59	29.69		173.71	184.88	147.71		31.14	32.99	27.96		
Sources		S.Em ±			CD (P = 0.05)		S.Em±		CD (P = 0.05)		S.Em ±		CD (P = 0.05)	
Date of sowing (D)		0.18			0.69		3.46		13.59		0.67		2.63	
Row Spacing (S)		0.17			0.51		4.00		12.31		0.63		1.93	
Genotype (G)		0.11			NS		1.95		5.78		0.25		0.74	
D X S		0.29			NS		6.92		NS		1.08		NS	
D X G		0.19			NS		3.37		NS		0.43		NS	
S X G		0.19			NS		3.37		NS		0.43		NS	
D X S X G		0.32			NS		5.84		NS		0.75		NS	

D = Date of sowing
D₁= Second fortnight of June (26th June)
D₂= First fortnight of July (13th July)
D₃= Second fortnight of July (30th July)

S= Row Spacing
S₁= 30 cm
S₂= 45 cm
S₃= 60 cm

G = Genotypes
G₁= DC-15
G₂= C-152

DAS= Days after sowing
FN = Fortnight
NS= Non Significant

At 55 DAS - harvest, significant difference was observed in LAD. Among the dates of sowing, the crop sown during second fortnight of June (83 days) recorded significantly higher LAD over, first fortnight of July (77 days) and second fortnight of July (73 days) and D_3 was on par with D_2 . Significantly higher LAD was recorded in 45 cm row spacing (82 days) over 30 cm row (78 days) and 60 cm row (73 days). Significant difference was observed in LAD between DC 15 (79 days) and C-152 (76 days). None of the interaction effects were significant except dates of sowing and planting geometry. The interaction D_1S_2 (second fortnight of June and 45 cm row) recorded significantly higher LAD (90 days) as compared to others. However, the LAD was the least in D_3S_3 (69 days).

4.1.8 Number of effective root nodules plant⁻¹

The number of effective nodules plant⁻¹ differed significantly at 35 DAS. Among the dates of sowing the crop sown on second fortnight of June (7.39) recorded significantly higher number of effective nodules plant⁻¹ over first fortnight of July (6.56) and second fortnight of July (6.17). Among the planting geometry, significantly higher number of effective root nodules plant⁻¹ was recorded in 45 cm row spacing (7.54) over 30 cm (6.69) and 60 cm row (5.88). There is no significant difference was observed between the genotypes and none of the interaction effects were significant (Table 11).

At 60 DAS, among the dates of sowing, the second fortnight of June recorded significantly higher number of effective root nodules plant⁻¹ (31.61) over rest of the sowing dates *i.e.* first fortnight of July (26.87) and second fortnight of July (26.84) and D_2 was on par with D_3 . Significantly higher number of effective root nodules plant⁻¹ was recorded in 45 cm row spacing (32.24) than 30 cm row (29.12) and 60 cm row (23.16). Significant difference was observed between two genotypes. DC 15 recorded significantly higher number of effective root nodules plant⁻¹ (29.06) over C-152 (27.29). None of the interaction effects were significant (Table 11).

4.1.9 Nodules dry weight (mg plant⁻¹)

The data on nodules dry weight (mg plant⁻¹) of cowpea genotypes as influenced by dates of sowing and planting geometry and their interactions are presented in Table 12.

At 35 DAS, the dry weight of nodules plant⁻¹ differed significantly. Among the dates of sowing, the crop sown on second fortnight of June (32.58 mg plant⁻¹) recorded significantly higher dry weight of nodules plant⁻¹ over first fortnight of July (31.15 mg plant⁻¹) and second fortnight of July (30.22 mg plant⁻¹). However among the planting geometry, significantly higher dry weight of nodules plant⁻¹ was recorded in 45 cm row spacing (32.59 mg plant⁻¹) over 30 cm row (31.66 mg plant⁻¹) and 60 cm row (29.69 mg plant⁻¹). There was no significant difference between the genotypes and none of the interaction effects were significant.

At 60 DAS, among the dates of sowing, the second fortnight of June recorded significantly higher nodules dry weight (183.66 mg plant⁻¹) over rest of the sowing dates *i.e.* first fortnight of July (163.86 mg plant⁻¹) and second fortnight of July (158.79 mg plant⁻¹) and D_2 was on par with D_3 . Significantly higher nodules dry weight was recorded in 45 cm row spacing (184.88 mg plant⁻¹) than 60 cm row (147.71 mg plant⁻¹) and it was on par with 30 cm row (173.71 mg plant⁻¹). Significant difference was observed between two genotypes. DC 15 recorded significantly higher nodules dry weight (171.97 mg plant⁻¹) over C-152 (165.56 mg plant⁻¹). None of the interaction effects were significant.

4.1.10 Total Dry matter production (g plant⁻¹)

The dry matter production differed significantly At 30 DAS. The crop sown on second fortnight of June recorded significantly higher dry matter production (3.52 g plant⁻¹) over second fortnight of July (3.04 g plant⁻¹) and it was on par with first fortnight of July (3.34 g plant⁻¹). Among the planting geometry, significantly higher dry matter production was recorded in 45 cm row spacing (3.67 g plant⁻¹) over 60 cm row (2.79 g plant⁻¹) and it was on par with 30 cm row (3.44 g plant⁻¹). There was no significant difference between the genotypes. None of the interaction effects were significant (Table 13).

At 55 DAS, among the dates of sowing, the second fortnight of June recorded significantly higher dry matter production (21.73 g plant⁻¹) over first fortnight of July (20.40 g plant⁻¹) and second fortnight of July (18.67 g plant⁻¹) sowing. Significantly higher dry matter production was recorded in 45 cm row spacing (22.71 g plant⁻¹) compared to 30 cm row (21.33 g plant⁻¹) and 60 cm row (16.76 g plant⁻¹). Likewise significantly higher dry matter production was recorded in genotype DC 15 (21.03 g plant⁻¹) than C-152 (19.51 g plant⁻¹). None of the interaction effects were significant except dates of

sowing and planting geometry. The interaction D_1S_2 recorded significantly higher dry matter production ($24.40 \text{ g plant}^{-1}$) over others except D_2S_2 ($23.93 \text{ g plant}^{-1}$) (first fortnight of July and 45 cm row) which is on par with D_1S_2 . However, the lower dry matter production was recorded in D_2S_3 ($15.77 \text{ g plant}^{-1}$) and D_3S_3 ($15.76 \text{ g plant}^{-1}$) compared to other treatment combinations (Table 13).

At harvest, dry matter production differed significantly among the dates of sowing. The crop sown on second fortnight of June ($48.98 \text{ g plant}^{-1}$) recorded significantly higher dry matter production over first fortnight of July ($42.22 \text{ g plant}^{-1}$) and second fortnight of July ($32.28 \text{ g plant}^{-1}$). Significantly higher dry matter production was recorded in 45 cm row spacing ($45.90 \text{ g plant}^{-1}$) compared to 60 cm row ($33.74 \text{ g plant}^{-1}$). However there was no significant difference between 45 and 30 cm row ($43.83 \text{ g plant}^{-1}$) spacings. Genotypes recorded significant difference for total dry matter production. DC 15 ($43.15 \text{ g plant}^{-1}$) was significantly superior to C-152 ($39.17 \text{ g plant}^{-1}$). None of the interaction effects were significant (Table 13).

4.1.11 Days for 50 per cent flowering

The data on days for 50 per cent flowering of cowpea genotypes as influenced by dates of sowing and planting geometry and their interactions are presented in Table 14.

Days for 50 per cent flowering differed significantly. Among the dates of sowing, the crop sown on second fortnight of June took more days (59.2 days) to attain 50 per cent flowering over second fortnight of July (53.1 days) and on par with first fortnight of July (57.4 days). There was no significant difference observed among planting geometry for flowering. Genotypes differed significantly to attain 50 per cent flowering. DC 15 took more days (57.30) to attain 50 per cent flowering than C-152 (55.85). None of the interaction effects were significant.

4.1.12 Days to physiological maturity

The data on days to physiological maturity of cowpea as influenced by dates of sowing and planting geometry and their interactions are presented in Table 15.

Days to physiological maturity of pods differed significantly due to different sowing windows. Among the different sowing dates, crop sown during second fortnight of June recorded more number of days (92.2) to physiological maturity of pods as compared to first and second fortnight of July (89.7 and 84.8 respectively). There was no significant difference observed due to planting geometry. Genotypes differed significantly to attain physiological maturity of pods. DC 15 recorded less number of days (84.3) than C-152 (93.5). None of the interaction effects were significant.

4.2 Yield and yield components of cowpea

4.2.1 Number of pods plant^{-1}

At harvest, number of pods plant^{-1} differed significantly. Among the dates of sowing, the crop sown on second fortnight of June recorded significantly higher number of pods plant^{-1} (15.22) over first fortnight of July (13.88) and second fortnight of July (9.43). Among the planting geometry, significantly higher number of pods plant^{-1} were recorded in 45 cm row spacing (13.59 plant^{-1}) over 60 cm row (11.02 plant^{-1}) and it was on par with 30 cm row (13.43 plant^{-1}). Significant difference in number of pods plant^{-1} was also observed between genotypes. DC 15 recorded higher number of pods (12.99 plant^{-1}) over C-152 (12.37) (Table 16). None of the interaction effects were significant.

4.2.2 Pod length (cm)

The data on pod length of cowpea genotypes as influenced by dates of sowing and planting geometry and their interactions are presented in Table 16.

At harvest, the effect of sowing windows and planting geometry was non-significant with respect to pod length, where as differed significantly with respect to genotypes. Higher pod length was recorded in DC 15 (17.13 cm) than C-152 (15.19 cm). None of the interaction effects were significant.

4.2.3 Number of seeds pod^{-1}

Number of seeds per pod differed significantly with respect to genotypes. Significantly higher number of seeds pod^{-1} was noticed with the genotype DC 15 (15.56) than C-152 (13.26). No significant difference was observed due to dates of sowing and planting geometry. Interaction effects due to sowing dates, row spacing and genotypes were found to be non-significant (Table 16).

Table 13: Total Dry matter production (g plant⁻¹) of cowpea genotypes as influenced by sowing windows and planting geometry

Treatment		Row spacing (S)											
		30 DAS				55 DAS				At harvest			
Date of sowing (D)	Genotypes (G)	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean
D ₁ : II FN of June	G ₁	3.56	3.96	3.09	3.54	22.32	24.88	19.66	22.29	53.28	58.29	42.69	51.42
	G ₂	3.54	3.94	3.05	3.51	21.76	23.92	17.85	21.17	47.70	53.35	38.57	46.54
	Mean	3.55	3.95	3.07	3.52	22.04	24.40	18.75	21.73	50.49	55.82	40.63	48.98
D ₂ : I FN of July	G ₁	3.49	3.89	2.67	3.35	23.08	24.39	17.05	21.51	47.29	50.15	36.14	44.53
	G ₂	3.45	3.87	2.65	3.32	19.91	23.47	14.50	19.29	41.61	45.17	32.95	39.91
	Mean	3.47	3.88	2.66	3.34	21.50	23.93	15.77	20.40	44.45	47.66	34.54	42.22
D ₃ : II FN of July	G ₁	3.31	3.19	2.64	3.05	20.81	20.16	16.90	19.29	37.39	35.68	27.42	33.50
	G ₂	3.28	3.16	2.65	3.03	20.10	19.45	14.62	18.05	35.70	32.79	24.67	31.05
	Mean	3.30	3.18	2.64	3.04	20.46	19.80	15.76	18.67	36.55	34.23	26.05	32.28
Mean of G ₁		3.45	3.68	2.80	3.31	22.07	23.14	17.87	21.03	45.99	48.04	35.42	43.15
Mean of G ₂		3.42	3.66	2.78	3.29	20.59	22.28	15.66	19.51	41.67	43.77	32.06	39.17
Mean		3.44	3.67	2.79		21.33	22.71	16.76		43.83	45.90	33.74	
Sources		S.Em ±		CD (P = 0.05)		S.Em±		CD (P = 0.05)		S.Em ±		CD (P = 0.05)	
Date of sowing (D)		0.05		0.19		0.28		1.11		0.25		0.99	
Row Spacing (S)		0.07		0.23		0.32		0.99		0.73		2.25	
Genotype (G)		0.01		NS		0.18		0.53		0.37		1.11	
D X S		0.13		NS		0.56		1.72		1.26		NS	
D X G		0.02		NS		0.31		NS		0.65		NS	
S X G		0.02		NS		0.31		NS		0.65		NS	
D X S X G		0.03		NS		0.53		NS		1.12		NS	

D = Date of sowing

D₁= Second fortnight of June (26th June)

D₂= First fortnight of July (13th July)

D₃= Second fortnight of July (30th July)

S= Row Spacing

S₁= 30 cm

S₂= 45 cm

S₃= 60 cm

G = Genotypes

G₁= DC-15

G₂= C-152

DAS= Days after sowing

FN = Fortnight

NS= Non Significant

Table 14: Days to 50 per cent flowering of cowpea genotypes as influenced by sowing windows and planting geometry

Treatment		Row spacing (S)			
Date of sowing (D)	Genotypes (G)	S ₁	S ₂	S ₃	Mean
D ₁ : II FN of June	G ₁	60.3	60.7	59.7	60.2
	G ₂	58.0	58.0	58.7	58.2
	Mean	59.2	59.3	59.2	59.2
D ₂ : I FN of July	G ₁	57.3	58.3	58.7	58.1
	G ₂	56.0	56.7	57.3	56.7
	Mean	56.7	57.5	58.0	57.4
D ₃ : II FN of July	G ₁	55.0	53.0	52.7	53.6
	G ₂	53.0	52.7	52.3	52.7
	Mean	54.0	52.8	52.5	53.1
Mean of G ₁		57.6	57.3	57.0	57.3
Mean of G ₂		55.7	55.8	56.1	55.9
Mean		56.6	56.6	56.6	
Sources		S.Em ±		CD (P = 0.05)	
Date of sowing (D)		1.03		4.0	
Row Spacing (S)		0.20		NS	
Genotype (G)		0.14		0.4	
D X S		0.34		NS	
D X G		0.24		NS	
S X G		0.24		NS	
D X S X G		0.42		NS	

D = Date of sowing

D₁= Second fortnight of June (26th June)

D₂= First fortnight of July (13th July)

D₃= Second fortnight of July (30th July)

S= Row Spacing

S₁= 30 cm

S₂= 45 cm

S₃= 60 cm

G = Genotypes

G₁= DC-15

G₂= C-152

DAS= Days after sowing

FN = Fortnight

NS= Non Significant

Table 15: Days to physiological maturity of cowpea genotypes as influenced by sowing windows and planting geometry

Treatment		Row spacing (S)			
Date of sowing (D)	Genotypes (G)	S ₁	S ₂	S ₃	Mean
D ₁ : II FN of June	G ₁	87.3	87.0	85.3	86.6
	G ₂	98.3	97.7	97.3	97.8
	Mean	92.8	92.3	91.3	92.2
D ₂ : I FN of July	G ₁	86.0	85.3	84.7	85.3
	G ₂	94.7	94.3	93.0	94.0
	Mean	90.3	89.8	88.8	89.7
D ₃ : II FN of July	G ₁	81.3	79.7	81.7	80.9
	G ₂	89.7	88.3	88.0	88.7
	Mean	85.5	84.0	84.8	84.8
Mean of G ₁		84.9	84.0	83.9	84.3
Mean of G ₂		94.2	93.4	92.8	93.5
Mean		89.6	88.7	88.3	
Sources		S.Em ±		CD (P = 0.05)	
Date of sowing (D)		0.37		1.44	
Row Spacing (S)		0.38		NS	
Genotype (G)		0.28		0.82	
D X S		0.66		NS	
D X G		0.48		1.42	
S X G		0.48		NS	
D X S X G		0.83		NS	

D = Date of sowing

D₁= Second fortnight of June (26th June)

D₂= First fortnight of July (13th July)

D₃= Second fortnight of July (30th July)

S= Row Spacing

S₁= 30 cm

S₂= 45 cm

S₃= 60 cm

G = Genotypes

G₁= DC-15

G₂= C-152

DAS= Days after sowing

FN = Fortnight

NS= Non Significant

Table 16: Number of pods plant⁻¹, pod length (cm) and number of Seeds pod⁻¹ of cowpea genotypes as influenced by sowing windows and planting geometry

Treatment		Row spacing (S)											
		Number of pods plant ⁻¹				Pod length (cm)				Number of seeds pod ⁻¹			
Date of sowing (D)	Genotypes (G)	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean
D ₁ : II FN of June	G ₁	16.33	16.90	13.40	15.54	17.17	17.23	17.10	17.17	15.83	15.83	15.73	15.80
	G ₂	15.73	16.27	12.70	14.90	15.27	15.60	15.13	15.33	13.17	13.53	13.23	13.31
	Mean	16.03	16.58	13.05	15.22	16.22	16.42	16.12	16.25	14.50	14.68	14.48	14.56
D ₂ : I FN of July	G ₁	14.00	14.60	12.63	13.74	17.07	17.13	17.00	17.07	15.37	15.30	15.63	15.43
	G ₂	13.50	13.73	11.83	13.02	15.53	15.10	15.07	15.23	13.43	13.20	13.17	13.27
	Mean	13.75	14.17	12.23	13.38	16.30	16.12	16.03	16.15	14.40	14.25	14.40	14.35
D ₃ : II FN of July	G ₁	10.80	10.30	7.90	9.67	17.07	17.13	17.27	17.16	15.83	15.27	15.27	15.46
	G ₂	10.20	9.73	7.67	9.20	14.97	14.93	15.13	15.01	13.13	13.33	13.17	13.21
	Mean	10.50	10.02	7.78	9.43	16.02	16.03	16.20	16.08	14.48	14.30	14.22	14.33
Mean of G ₁		13.71	13.93	11.31	12.99	17.10	17.17	17.12	17.13	15.68	15.47	15.54	15.56
Mean of G ₂		13.14	13.24	10.73	12.37	15.26	15.21	15.11	15.19	13.24	13.36	13.19	13.26
Mean		13.43	13.59	11.02		16.18	16.19	16.12		14.46	14.41	14.37	
Sources		S.Em ±		CD (P = 0.05)		S.Em±		CD (P = 0.05)		S.Em ±		CD (P = 0.05)	
Date of sowing (D)		0.18		0.72		0.08		NS		0.06		NS	
Row Spacing (S)		0.22		0.68		0.07		NS		0.07		NS	
Genotype (G)		0.08		0.25		0.08		0.25		0.05		0.16	
D X S		0.39		NS		0.12		NS		0.12		NS	
D X G		0.14		NS		0.14		NS		0.10		NS	
S X G		0.14		NS		0.14		NS		0.10		NS	
D X S X G		0.25		NS		0.25		NS		0.16		NS	

D = Date of sowing
D₁= Second fortnight of June (26th June)
D₂= First fortnight of July (13th July)
D₃= Second fortnight of July (30th July)

S= Row Spacing
S₁= 30 cm
S₂= 45 cm
S₃= 60 cm

G = Genotypes
G₁= DC-15
G₂= C-152

DAS= Days after sowing
FN = Fortnight
NS= Non Significant

Table 17: Seed weight plant⁻¹ (g) and test weight (g) of cowpea genotypes as influenced by sowing windows and planting geometry

Treatment		Row spacing (S)							
		Seed weight plant ⁻¹ (g)				Test weight (g)			
Date of sowing (D)	Genotypes (G)	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean
D ₁ : II FN of June	G ₁	21.97	22.40	19.87	21.41	10.15	10.23	10.10	10.16
	G ₂	20.50	20.73	18.87	20.03	9.78	9.88	9.97	9.88
	Mean	21.23	21.57	19.37	20.72	9.97	10.05	10.04	10.02
D ₂ : I FN of July	G ₁	21.53	21.97	19.00	20.83	10.09	10.15	10.08	10.11
	G ₂	19.93	19.83	18.03	19.27	9.89	9.92	9.86	9.89
	Mean	20.73	20.90	18.52	20.05	9.99	10.03	9.97	10.00
D ₃ : II FN of July	G ₁	18.20	18.03	16.23	17.49	10.21	10.20	10.06	10.16
	G ₂	17.80	16.77	15.87	16.81	9.37	9.29	9.18	9.28
	Mean	18.00	17.40	16.05	17.15	9.79	9.74	9.62	9.72
Mean of G ₁		20.57	20.80	18.37	19.91	10.15	10.19	10.08	10.14
Mean of G ₂		19.41	19.11	17.59	18.70	9.68	9.69	9.67	9.68
Mean		19.99	19.96	17.98		9.91	9.94	9.88	
Sources		S.Em ±		CD (P = 0.05)		S.Em±		CD (P = 0.05)	
Date of sowing (D)		0.14		0.56		0.09		NS	
Row Spacing (S)		0.11		0.34		0.05		NS	
Genotype (G)		0.10		0.31		0.04		0.12	
D X S		0.19		NS		0.09		NS	
D X G		0.18		NS		0.07		0.22	
S X G		0.18		NS		0.07		NS	
D X S X G		0.31		NS		0.13		NS	

D = Date of sowing

D₁= Second fortnight of June (26th June)

D₂= First fortnight of July (13th July)

D₃= Second fortnight of July (30th July)

S= Row Spacing

S₁= 30 cm

S₂= 45 cm

S₃= 60 cm

G = Genotypes

G₁= DC-15

G₂= C-152

DAS= Days after sowing

FN = Fortnight

NS= Non Significant

4.2.4 Seed weight plant⁻¹

The data on seed weight plant⁻¹ of cowpea genotypes as influenced by dates of sowing and planting geometry and their interactions are presented in Table 17.

Date of sowing influenced significantly seed weight per plant. June second fortnight sowing recorded significantly higher seed weight per plant (20.72 g) followed by July first fortnight (20.05 g) and July second fortnight (17.15 g) sowing. Seed yield was also significantly influenced by row spacings. The 30 cm row spacing recorded significantly higher seed weight (19.99 g) over 60 cm row spacing (17.98 g plant⁻¹) and it was on par with 45 cm row spacing (19.96 g). Genotypes differed significantly with respect to seed weight plant⁻¹. Genotype DC 15 recorded significantly higher seed weight (19.91 g) than genotype C-152 (18.70 g plant⁻¹). Interaction effects due to sowing dates, row spacing and genotypes were found to be non-significant.

4.2.5 Test weight (g)

The effects of sowing dates and planting geometry does not influence significantly on test weight. Genotypes had significant difference on 100 seed weight. Genotype DC 15 had significantly higher 100 seed weight of 9.89 g than the genotype C-152 which is recorded 9.78 g.

None of the interaction effects were shown significant differences except date of sowing and genotypes. Genotype DC 15 sown during second fortnight of June and July recorded significantly higher test weight (10.16 g each) and it was on par with the crop sown during first fortnight of June with DC 15 (10.11 g) (Table 17).

4.2.6 Seed yield (kg ha⁻¹)

The data on seed yield of cowpea genotypes as influenced by dates of sowing and planting geometry and their interactions are presented in Table 18.

Cowpea seed yield differed significantly among the dates of sowing. The crop sown on second fortnight of June recorded significantly higher seed yield (1155 kg ha⁻¹) over first fortnight of July (1029 kg ha⁻¹) and second fortnight of July (686 kg ha⁻¹). Among the spacings, significantly higher seed yield was recorded in 45cm row spacing (1062 kg ha⁻¹) over 60 cm row spacing (774 kg ha⁻¹) and was on par with 30 cm row spacing (1034 kg ha⁻¹). Significant difference was observed in seed yield between two genotypes. Genotype DC 15 recorded significantly higher seed yield (1026 kg ha⁻¹) than genotype C-152 (887 kg ha⁻¹).

None of the interactions effects were significant except dates of sowing × varieties and spacing × varieties. The interaction D₁G₁ (second fortnight of June and DC 15) (1239 kg ha⁻¹) was significantly superior to other interactions of dates of sowing and genotypes. The interaction S₂G₁ (45 cm row spacing and DC 15) (1140 kg ha⁻¹) was significant to other interactions of spacing and genotypes.

The seed yield of cowpea was non-significant for dates of sowing, planting geometry and genotypes interactions. Among the treatment combinations, the variety DC 15 sown on second fortnight of June with 45cm row spacing (D₁S₂G₁) recorded maximum yield (1343 kg ha⁻¹) over other treatment combinations. The lower seed yield of cowpea (489 kg ha⁻¹) was noticed in crop sown on second fortnight of July, the variety C-152 with 60cm row spacing (D₃S₃G₂).

4.2.7 Haulm yield (kg ha⁻¹)

Haulm yield was significantly influenced due to sowing dates. June second fortnight sown crop recorded significantly higher haulm yield (2535 kg ha⁻¹) than July second fortnight sown crop (1574 kg ha⁻¹) and it was on par with the crop sown during first fortnight of July (2350 kg ha⁻¹). Planting geometry recorded significant difference for haulm yield. Higher haulm yield was recorded in 45 cm row spacing (2373 kg ha⁻¹) and it was on par with 30 cm row spacing (2296 kg ha⁻¹) than 60 cm row spacing (1791 kg ha⁻¹). The genotypes also had significant difference for haulm yield. Higher haulm yield was noticed in genotype DC 15 (2279 kg ha⁻¹) than C-152 (2027 kg ha⁻¹) (Table 18).

None of the interaction effects were differed significantly for haulm yield except dates of sowing and genotype. Genotype DC 15 sown on second fortnight of June (D₁G₁) recorded significantly higher haulm yield (2647 kg ha⁻¹) as compared to other interaction effects. However D₃G₂ (Second fortnight of July and C-152) recorded significantly lower haulm yield (Table 18).

4.2.8 Per cent Harvest Index (HI)

The data on harvest index (HI) of cowpea genotypes as influenced by dates of sowing and planting geometry and their interactions are presented in Table 18).

Harvest index differed significantly due to dates of sowing. Among the dates of sowing the crop sown on second fortnight of June and first fortnight of July recorded significantly higher HI (30.34 and 29.92 respectively) over the second fortnight of July sowing (28.86). Among the planting geometry, significantly higher HI was recorded in 30 and 45 cm row (30.17 and 29.98 respectively) over 60 cm (28.98). Significant difference in HI was also observed between genotypes. DC 15 recorded higher HI (29.98) than C-152 (29.43).

None of the interaction effects were significant except dates of sowing and genotypes. The crop sown on second fortnight of June with DC 15 recorded significantly higher HI (30.86) than other treatment combinations. Similarly, the dates of sowing and planting geometry interaction effects also significantly influenced the HI. The crop sown during second fortnight of June with 30 and 45 cm row spacings recorded significantly higher HI (30.80 and 30.93 respectively) than other dates of sowing and planting geometry interactions.

4.3 Quality parameter of cowpea

4.3.1 Grain protein content (per cent)

The data on grain protein content of cowpea genotypes as influenced by dates of sowing and planting geometry and their interactions are presented in Table 19.

There was no significant difference in grain protein content due to the dates of sowing. Similarly planting geometry also had no significant difference for grain protein content. Significant difference was observed in grain protein content between the genotypes. DC 15 recorded significantly higher protein content (24.26 %) than C-152 (21.33 %). None of the interaction effects were significant.

4.4 Economics of cowpea

4.4.1 Gross return (₹ ha⁻¹)

The gross return obtained in the crop sown during second fortnight of June was significantly higher (₹ 48230 ha⁻¹) than first fortnight of July (₹ 43022 ha⁻¹) and second fortnight of July (₹ 28686 ha⁻¹). However, among the planting geometry 45 cm row spacing recorded significantly higher gross return (₹ 44378 ha⁻¹) followed by 30 cm (₹ 43179 ha⁻¹) over 60 cm row (₹ 32382 ha⁻¹). Significant difference in gross return was observed in genotype DC 15 (₹ 42865 ha⁻¹) as compared to C-152 (₹ 37094 ha⁻¹).

Gross return of cowpea genotypes were significantly influenced by dates of sowing and varieties. Among the treatment combinations, variety DC 15 sown on second fortnight of June recorded significantly higher gross return (₹ 51686 ha⁻¹) over the other treatment combinations. However, gross return was also significantly influenced by planting geometry and genotype. DC 15 sown in 45 cm row recorded significantly higher gross return (₹ 47605 ha⁻¹) over other combinations. The lower gross return was observed in genotype C-152 sown on second fortnight of July with 60 cm row spacing (₹ 20452 ha⁻¹) (Table 20).

4.4.2 Net return (₹ ha⁻¹)

Significantly higher net return was recorded in second fortnight of June (₹ 32816 ha⁻¹) followed by first fortnight of July (₹ 26403 ha⁻¹) and second fortnight of July (₹ 13839 ha⁻¹). Among the planting geometry, 45 cm row recorded significantly higher net return (₹ 28751 ha⁻¹) which was on par with 30 cm (₹ 27552 ha⁻¹) over 60 cm row (₹ 16755 ha⁻¹). Significant difference was observed in genotype DC 15 (₹ 27238 ha⁻¹) over C-152 (₹ 21468 ha⁻¹) in terms of net return (Table 20).

The net return of cowpea genotypes were significantly influenced by dates of sowing and varieties. Among the treatment combinations, variety DC 15 sown on second fortnight of June recorded significantly higher gross return (₹ 36272 ha⁻¹) over the other treatment combinations. However net return was also significantly influenced by planting geometry and genotype. The DC 15 sown in 45 cm row recorded significantly higher gross return (₹ 31978 ha⁻¹) over other combinations. The lower gross return was observed in genotype C-152 sown on second fortnight of July with 60 cm row spacing (₹ 5605 ha⁻¹) (Table 20).

Table 18: Seed yield (kg ha⁻¹), haulm yield (kg ha⁻¹) and harvest index (%) of cowpea genotypes as influenced by sowing windows and planting geometry

Treatment		Row spacing (S)											
		Seed yield (kg ha ⁻¹)				Haulm yield (kg ha ⁻¹)				Harvest index (%)			
Date of sowing (D)	Genotypes (G)	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean	S1	S2	S3	Mean
D ₁ : II FN of June	G ₁	1303	1343	1071	1239	2712	2830	2399	2647	31.70	31.44	29.46	30.86
	G ₂	1100	1180	933	1071	2478	2597	2196	2424	29.90	30.43	29.11	29.81
	Mean	1202	1262	1002	1155	2595	2713	2298	2535	30.80	30.93	29.28	30.34
D ₂ : I FN of July	G ₁	1228	1233	877	1113	2736	2809	2045	2530	30.51	30.15	29.52	30.06
	G ₂	1030	1053	750	944	2384	2358	1768	2170	29.73	30.43	29.21	29.79
	Mean	1129	1143	813	1029	2560	2583	1907	2350	30.12	30.29	29.36	29.92
D ₃ : II FN of July	G ₁	813	842	523	726	1831	1946	1205	1661	29.64	28.79	28.63	29.02
	G ₂	727	720	489	645	1634	1697	1132	1488	29.52	28.62	27.94	28.69
	Mean	770	781	506	686	1733	1821	1168	1574	29.58	28.70	28.28	28.86
Mean of G ₁		1115	1140	824	1026	2426	2528	1883	2279	30.61	30.12	29.20	29.98
Mean of G ₂		952	984	724	887	2166	2217	1699	2027	29.72	29.83	28.75	29.43
Mean		1034	1062	774		2296	2373	1791		30.17	29.98	28.98	
Sources		S.Em ±		CD (P = 0.05)		S.Em±		CD (P = 0.05)		S.Em ±		CD (P = 0.05)	
Date of sowing (D)		18.75		73.64		52.31		205.38		0.11		0.43	
Row Spacing (S)		11.88		36.62		32.29		99.50		0.11		0.34	
Genotype (G)		5.13		15.24		14.43		42.88		0.08		0.23	
D X S		20.58		NS		55.93		NS		0.19		0.58	
D X G		8.89		26.40		25.00		74.27		0.13		0.40	
S X G		8.89		26.40		25.00		NS		0.13		NS	
D X S X G		15.39		NS		43.30		NS		0.23		NS	

D = Date of sowing
D₁= Second fortnight of June (26th June)
D₂= First fortnight of July (13th July)
D₃= Second fortnight of July (30th July)

S= Row Spacing
S₁= 30 cm
S₂= 45 cm
S₃= 60 cm

G = Genotypes
G₁= DC-15
G₂= C-152

DAS= Days after sowing
FN = Fortnight
NS= Non Significant

Table 19: Protein (%) content of cowpea genotypes as influenced by sowing windows and planting geometry

Treatment		Row spacing (S)			
		Protein content (%)			
Date of sowing (D)	Genotypes (G)	S ₁	S ₂	S ₃	Mean
D ₁ : II FN of June	G ₁	24.33	24.40	24.17	24.30
	G ₂	21.21	21.23	21.40	21.28
	Mean	22.77	22.82	22.78	22.79
D ₂ : I FN of July	G ₁	24.53	24.32	24.00	24.29
	G ₂	21.67	21.13	21.70	21.50
	Mean	23.10	22.73	22.85	22.80
D ₃ : II FN of July	G ₁	24.15	24.23	24.13	24.18
	G ₂	21.20	21.17	21.23	21.20
	Mean	22.68	22.70	22.68	22.7
Mean of G ₁		24.34	24.32	24.10	24.26
Mean of G ₂		21.36	21.18	21.44	21.33
Mean		22.84	22.75	22.73	
Sources		S.Em ±		CD (P = 0.05)	
Date of sowing (D)		0.06		NS	
Row Spacing (S)		0.10		NS	
Genotype (G)		0.07		0.20	
D X S		0.17		NS	
D X G		0.12		NS	
S X G		0.12		NS	
D X S X G		0.20		NS	

D = Date of sowing

D₁= Second fortnight of June (26th June)

D₂= First fortnight of July (13th July)

D₃= Second fortnight of July (30th July)

S= Row Spacing

S₁= 30 cm

S₂= 45 cm

S₃= 60 cm

G = Genotypes

G₁= DC-15

G₂= C-152

DAS= Days after sowing

FN = Fortnight

NS= Non Significant

Table 20: Gross return, Net return and B:C ratio of cowpea genotypes as influenced by sowing windows and planting geometry

Treatment		Row spacing (S)											
		Gross return (₹ ha ⁻¹)				Net return (₹ ha ⁻¹)				B:C ratio			
Date of sowing (D)	Genotypes (G)	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean
D₁ : II FN of June	G ₁	54303	55997	44759	51686	38889	40583	29345	36272	3.52	3.63	2.90	3.35
	G ₂	45983	49278	39063	44775	30569	33864	23649	29361	2.98	3.20	2.53	2.90
	Mean	50143	52637	41911	48230	34729	37223	26497	32816	3.25	3.41	2.72	3.13
D₂ : I FN of July	G ₁	51309	51580	36703	46531	34690	34961	20084	29912	3.09	3.10	2.21	2.80
	G ₂	43107	44020	31414	39514	26488	27401	14795	22895	2.59	2.65	1.89	2.38
	Mean	47208	47800	34059	43022	30589	31181	17440	26403	2.84	2.88	2.05	2.59
D₃ : II FN of July	G ₁	33998	35237	21897	30377	19151	20390	7050	15530	2.29	2.37	1.47	2.05
	G ₂	30374	30158	20452	26995	15527	15311	5605	12148	2.05	2.03	1.38	1.82
	Mean	32186	32697	21175	28686	17339	17850	6328	13839	2.17	2.20	1.43	1.93
Mean of G ₁		46537	47605	34453	42865	30910	31978	18826	27238	2.97	3.04	2.20	2.73
Mean of G ₂		39821	41152	30310	37094	24195	25525	14683	21468	2.54	2.63	1.93	2.37
Mean		43179	44378	32382		27552	28751	16755		2.75	2.83	2.06	
Sources		S.Em ±		CD (P = 0.05)		S.Em±		CD (P = 0.05)		S.Em ±		CD (P = 0.05)	
Date of sowing (D)		789		3097		789		3097		0.05		0.20	
Row Spacing (S)		498		1536		498		1536		0.03		0.10	
Genotype (G)		213		634		213		634		0.01		0.04	
D X S		863		NS		863		NS		0.06		NS	
D X G		369		1097		369		1097		0.02		0.07	
S X G		369		1097		369		1097		0.02		0.07	
D X S X G		640		NS		640		NS		0.04		NS	

D = Date of sowing

D₁= Second fortnight of June (26th June)

D₂= First fortnight of July (13th July)

D₃= Second fortnight of July (30th July)

S= Row Spacing

S₁= 30 cm

S₂= 45 cm

S₃= 60 cm

G = Genotypes

G₁= DC-15

G₂= C-152

DAS= Days after sowing

FN = Fortnight

NS= Non Significant

4.4.3 Benefit cost ratio

Significantly higher B:C ratio was recorded in second fortnight of June (3.13) than first fortnight of July (2.59) and second fortnight of July (1.93). Among the planting geometry, 45 cm row recorded significantly higher B:C ratio (2.83) which was on par with 30 cm (2.75) over 60 cm row (2.06). Significant difference was observed in genotype DC 15 (2.73) over C-152 (2.37) in terms of B:C ratio (Table 20).

The B:C ratio of cowpea genotypes were significantly influenced by dates of sowing. Among the treatment combinations, variety DC 15 sown on second fortnight of June recorded significantly higher B:C ratio (3.35) over other treatment combinations. However, B:C ratio also significantly influenced by planting geometry and genotype. DC 15 sown in 45 cm row recorded significantly higher B:C ratio (3.04) over other combinations. The lower B:C ratio was observed in genotype C-152 sown on second fortnight of July with 60 cm row spacing (1.38) (Table 20).

DISCUSSION

Among the various factors impacting the growth, yield and quality of cowpea, selection of suitable genotype and date of sowing play a vital role. The present investigation was undertaken to identify suitable genotypes for *kharif* and to find out suitable dates of sowing for obtaining maximum yield. The field trial was carried out to study the “Response of cowpea genotypes (C-152 and DC 15) to sowing windows (II fortnight of June, I fortnight July and II fortnight of July) and planting geometry (30, 45 and 60 cm row) at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. The experiment was conducted in split-split plot design with three replications. The results of the experiment obtained are discussed in this chapter.

5.1 Weather condition and crop performance

The crop growth to a large extent depends on interaction between genotype and environment in which it is grown. Fluctuations in environmental conditions greatly influence the crop dynamics and yielding ability.

The annual rainfall received during 2013 was 740.4 mm distributed in 63 rainy days (Fig. 1). It was 4 per cent higher than the average rainfall of 63 years (711.1 mm). The rainfall during cropping period (June-November) was 559.4 mm distributing in 48 rainy days (Appendix I). The rainfall received during second fortnight of June to first fortnight of July ensured sufficient soil moisture for germination, emergence and early establishment of seedlings for first two dates of sowing (II fortnight of June and I fortnight of July, respectively). However the late sown (II fortnight of July) crop did not get sufficient moisture during crop growth stage. Even though the maximum rainfall during the year was received in the month of July (177.8 mm) followed by September (133.6 mm), the distribution of rainfall was erratic. Hence, delayed sown (II fortnight of July) crop suffered due to moisture stress during early growth, flowering and pod formation stage. The other parameters namely maximum and minimum temperature, relative humidity and photoperiodic response did not affect adversely on crop growth and yield except on flowering. The mean maximum temperature during the period of experiment ranged from 29.0 °C (November) to 25.4 °C (July), while the minimum temperature was between 15.8 °C (November) to 29.0 °C (October). The mean relative humidity varied from 64 per cent in the month of November to 89.0 per cent in the month of July 2013 (Fig. 1).

5.2 Effect of sowing windows on growth and yield

Time of sowing plays an important role to exploit genetic potentiality of a genotype as it provides optimum growing condition such as temperature, light, humidity and rain fall during crop growth stage. Sowing date determines the time available for vegetative phase before the onset of flowering which is mainly influenced by photoperiod. Among the agronomic practices in field crops, sowing at optimum time is an important non cash input that results in considerable increase in the yield. This indicates that a favourable soil and climatic conditions are important to the crop for the expression of their genetic potential.

Cowpea is normally sown during June to August in northern transitional zone of Karnataka. However, in recent years due to erratic rainfall and climate change situations the optimum sowing time is extended either too early or beyond the recommended time. Madhu (2013) reported that delayed sowing significantly reduced the seed yield and haulm yield in mungbean. In present investigation (Fig. 3) June second fortnight (D₁) sowing produced significantly higher seed yield (1155 kg ha⁻¹) compared to D₂ (July first fortnight sowing, 1029 kg ha⁻¹) and D₃ (July second fortnight sowing, 686 kg ha⁻¹). D₁ produced 11 and 41 per cent higher grain yield over D₂ and D₃ respectively. The higher seed yield obtained in early sown crop was due to higher soil moisture during cropping period as a result of receipt of 97.2 and 134.6 mm rainfall during August and September respectively. This coincides with the flowering and pod formation stage of early sown crop (Appendix I) and these results are in conformity with findings of Babalola (1980) reported that the grain yield reduction was higher (36.8 %) when stress imposed at flowering and podding stage in cowpea (Plate 2).

Similarly Rima and Nabam (2013) reported that compared to July first fortnight and July second fortnight sowing, significantly higher seed yield, haulm yield and harvest index were recorded in cowpea sown in June second fortnight.

The higher seed yield in early sown crop (II fortnight of June) is attributed to higher values of yield components over the late sown crop. There was significantly considerable increase in the values of important yield attributing characters like number of pods plant⁻¹ (15.52) and seed weight plant⁻¹

(20.72 g) in early sown crop as compared to late sown crop I fortnight of July (13.38 and 20 g respectively) and II fortnight of July (9.43 and 17.5 g respectively), while no significant difference was observed in pod length, number of seeds pod⁻¹ and test weight due to different sowing dates. This might be due to these are conserved characters of genotypes which are genetically controlled (Fig. 4 and 5).

Similar results of higher seed yield in early sown crop compared to late sown crop were reported by many workers (Yadav, 2003; Rima and Nabam, 2013 in cowpea, Soomro and Khan, 2003; Abdur Rahman *et al.*, 2004; Sadeghipour, 2008; Madhu, 2013 in mungbean), and they confined that early sowing significantly influences seed yield and delay in sowing causes a substantial decrease in growth and yield attributing parameters.

Increase in seed yield of early sown crop was mainly due to the production of higher total dry matter and its partitioning towards productive parts. The total dry matter production at harvest in early sown crop was 48.98 g plant⁻¹ (Fig. 9) which was significantly higher than crop sown on first and second fortnight of July (42.22 and 32.28 g plant⁻¹, respectively). This is mainly because of increased production of assimilates contributing to higher total dry matter production at all growth stages in early sown crop. Increased production of photosynthates is thus due to higher values of LAI and LAD. In early sown crop LA and LAI were also significantly high which were perhaps responsible for higher values in yield components ultimately resulting increased seed yield. Significantly more plant height (95.8 cm), number of primary branches (9.74), LA (106.1 dm²), LAI (3.54) and LAD (58.3 days) was recorded in early sown crop (second fortnight of June) than crop sown on first fortnight of July (86.4 cm, 9.5, 99.6 dm², 3.32 and 52.8 days respectively) and second fortnight of July (83.9 cm, 8.0, 95.1 dm², 3.17 and 49.7 days respectively) (Fig. 10, 11, 12). These results are in conformity with the findings of Rima and Nabam (2013) for LAI and total dry matter production in cowpea, Yadav (2003) for plant height and number of pods in cowpea, Soomro and Khan (2003) for plant height, number of branches plant⁻¹ and number of pods plant⁻¹ in mung bean.

Significantly higher number of effective root nodules and nodule dry weight were also recorded in second fortnight of June (31.6 and 183 mg plant⁻¹) as compared to first fortnight of June (26.8 and 163.8 mg plant⁻¹) and second fortnight of July (26 and 158.8 mg plant⁻¹). It was mainly because of presence of favourable soil moisture, aeration and soil temperature for the activity of rhizobium. Guriqbal Singh (2012) reported that number of nodules and their dry weight plant⁻¹ was higher in case of early sowing while minimum in delay sowing in urdbean.

There was significant difference between the genotypes in respect of grain yield at all the three dates of sowing (Fig. 3). The genotype DC 15 recorded significantly higher yield than C-152. Both the genotypes produced significantly more number of pods plant⁻¹ in early date of sowing as compared to late sowing. These results are similar to the findings of Abdur Rahman *et al.* (2004) and Madhu (2013) in mungbean, they also have noticed that the AAU-39 was more potential yielding variety in all the four dates of sowing followed by ML-131. Early sown crop of first fortnight of June produced significantly more number of pods followed by second fortnight of June sown crop and least number of pods was observed in last sowing date *i.e.* second fortnight of July.

Days to 50 per cent flowering was significantly influenced by sowing dates (Fig. 8). More number of days to 50 per cent flowering was observed in early sown crop (second fortnight of June) over late sown crop (second fortnight of July) and it was on par with first fortnight of July. Early sown crops took more days to flower because of prolonged vegetative phase and photoperiod than the late sown crop. The different trend was observed due to occurrence of higher maximum and minimum temperature that probably accelerated the process of development; as a result duration of 50 per cent flowering as well as physiological maturity might be varied. Early sown crop might have availed more growing degree days (GDD), photothermal units (PTU) and heliothermal units (HTU) at physiological maturity and with each delay in sowing GDD, PTU and HTU decreased. Hence crop sown during second fortnight of June recorded more number of days to attain physiological maturity of pods and it was decreased in delayed sowing. These results are in consistence with the findings of Guriqbal Singh *et al.* (2010), who reported that with delayed sowing, days to 50 per cent flowering as well as days to maturity were reduced in all the genotypes of mungbean. Similar results were obtained by Rhandzu (2007), reported that planting date cause differences in flowering period among the cowpea genotypes.

Meteorological data suggest that early sown crop benefited from monsoon rainfall during July and August. The crop attained vigorous vegetative growth prior to onset of flowering that was later used for pod formation and grain filling. However the crop sown during first fortnight of July was.

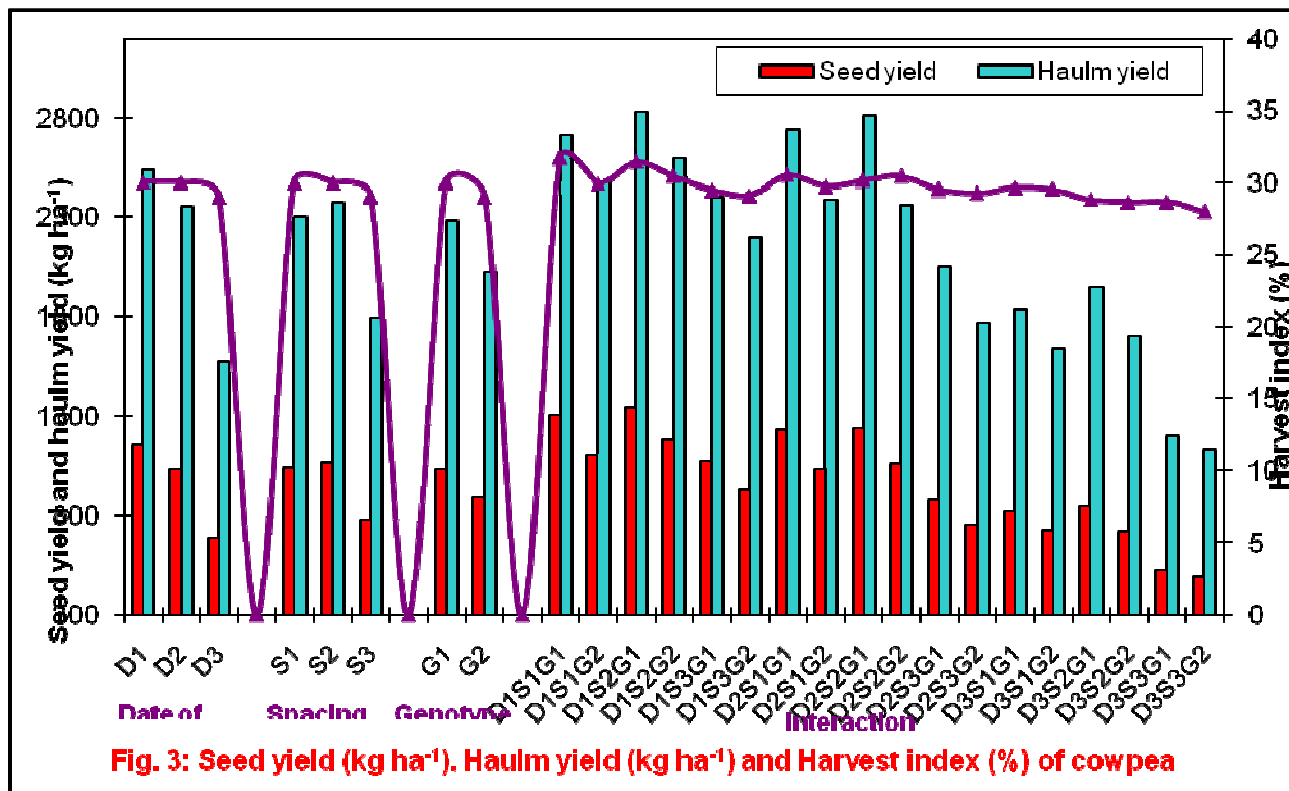


Fig. 3: Seed yield (kg ha⁻¹), Haulm yield (kg ha⁻¹) and Harvest index (%) of cowpea genotypes as influenced by sowing windows and planting geometry



Plate 2. Crop growth in different sowing windows

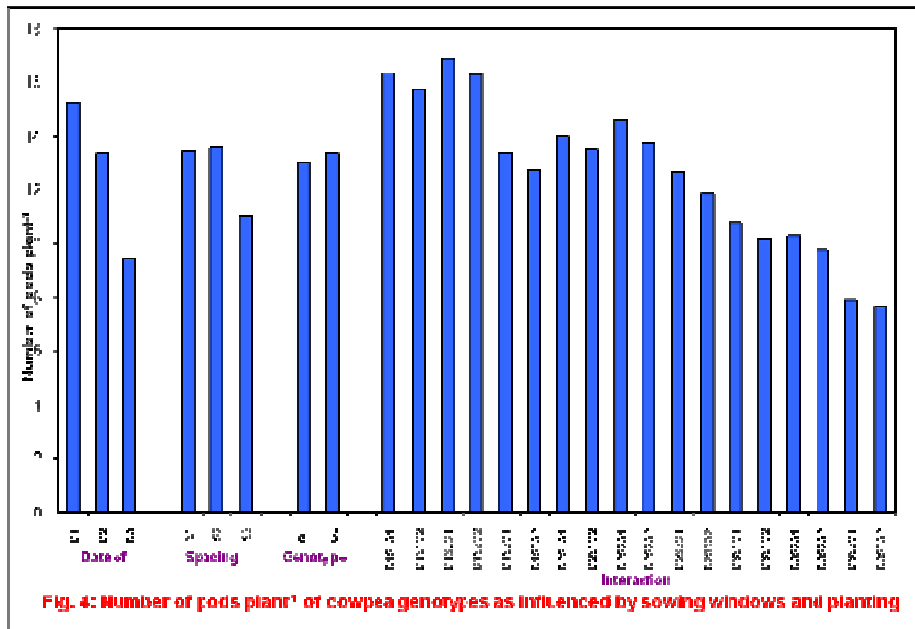


Fig. 4: Number of pods plant⁻¹ of cowpea genotypes as influenced by sowing windows and planting geometry

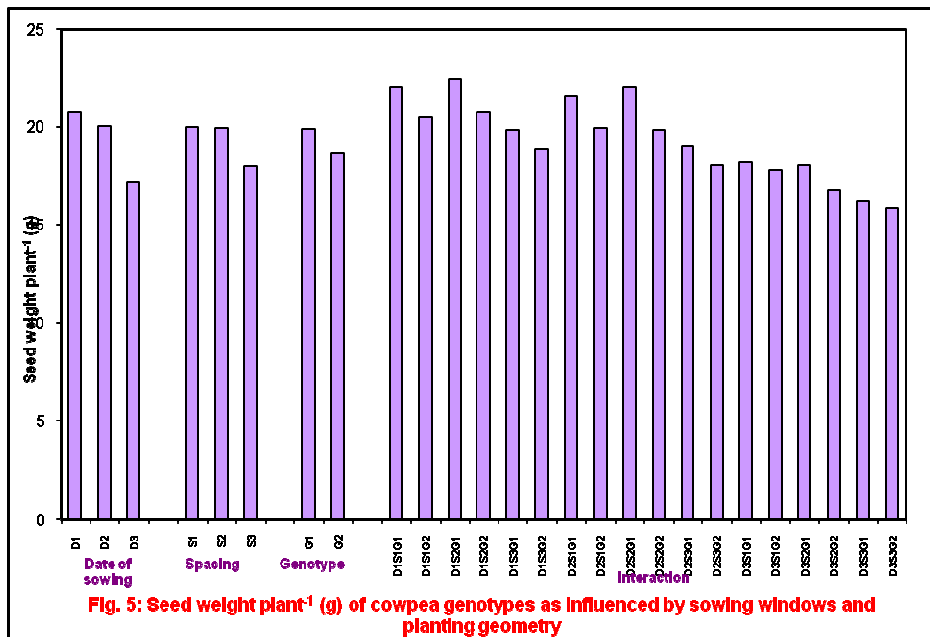


Fig. 5: Seed weight plant⁻¹ (g) of cowpea genotypes as influenced by sowing windows and planting geometry

severely infested by lepidopteron pests due to prevailed favourable conditions and also crop was susceptible for lodging. Late sown crop suffered from dry spells resulting in stunted growth. In addition relatively high diurnal fluctuation in temperatures associated with low night temperature might have hampered grain formation. Based on the observation it is concluded that prevailing common practice of cowpea sowing during second fortnight of July or even in late may cause substantial reduction in grain yield. There for early sowing (II fortnight of June) of cowpea is beneficial for obtaining higher yield especially for determinate genotypes.

5.3 Effect of planting geometry on growth and yield

Yield potential of a particular genotype in a given environment can be exploited under optimum planting geometry where competition between the plants is minimum. This can be achieved with optimum planting geometry which not only utilizes soil moisture and nutrients more effectively but also avoids excessive competition among the plants. However, beyond a certain limit yield cannot be varied significantly. Hence, optimum row spacing allows the crop to achieve its potential yield.

In present investigation, row spacings were tested at three levels viz., 30, 45 and 60 cm to identify the optimum planting geometry to achieve yield potential of the two genotypes. Same seed rate was used to maintain the uniform plant population in all the three row spacings by adjusting intra row spacing.

Significant differences in seed yield were obtained due to different levels of row spacing. Maximum seed and haulm yield was recorded with 45 cm spacing (1062 and 2373 kg ha⁻¹, respectively) which was significantly higher than 60 cm spacing (774 and 1791 kg ha⁻¹, respectively) and no significant differences were observed between 45 and 30 cm spacings (1034 and 2296 kg ha⁻¹) (Fig. 3 and Plate 3).

Shivananda (2005) reported consequent upon improved growth and yield attributes significantly higher seed and haulm yields (1450 and 2626 kg ha⁻¹, respectively) were recorded with 45 x 10 cm than 30 x 10 cm and 60 x 10 cm. These results are also in agreement with the findings of Azarhash *et al.* (2007) in common bean. They found that inter and intra row spacings have significant influence on yield and yield components.

Higher seed yield (Fig. 4 and 5) with row spacing of 45 and 30 cm could be attributed due to significant increase in the number of pods plant⁻¹ (13.59 and 13 respectively) and seed weight plant⁻¹ (19.96 and 19.99 g plant⁻¹). These values were significantly lower at spacing of 60 cm (11.02 and 17.98 g plant⁻¹) due to increased competition among the plants within the rows for the space, light and nutrients and there is no significant difference was observed between 45 and 30 cm row spacings. Mureithi *et al.* (2012) reported that increase in intra row spacing to 20 cm in french bean recorded significantly higher plant height, number of branches, leaf area and dry weight and it was decreased significantly with further increase in the intra row spacing. At 45 and 30 cm row spacings, individual plant might have received favourable environment to utilize fully the available natural resources resulting in improvements in the yield components as compared to 60 cm row spacings. The higher seed weight plant⁻¹ was recorded in 30 cm row spacing this decreased by 11 per cent with increase in row spacing from 30 to 60 cm and reduction in intra row spacing. Row spacing had no effect on the pod length, number of seeds pod⁻¹ and test weight. This might be due to genotypic characters.

Difference in various yield components which led to significant yield differences could be traced back to significant variations in dry matter production. Improvement in the yield components with medium row spacing of 45 cm can be related to the differences in dry matter production in plants. The total dry matter production plant⁻¹ increased with 45 cm row spacing at all the growth stages. At harvest, 45 cm row spacing recorded significantly higher total dry matter production (45.9 g plant⁻¹) over 30 cm (43.8 g plant⁻¹) and 60 cm (33.7 g plant⁻¹) row spacing (Fig. 9). Maximum dry matter production at 45 cm row spacing can be attributed because of uniform distribution of plant population led to better environment with respect to soil moisture, nutrition and availability of light to the plants and increased photosynthetic efficiency. Proportionately more light was transmitted within the canopy of the plants in the field which was attributed to the scattering and reflection by adjacent leaves in open canopy than closed canopy.

Higher dry matter production and its accumulation in reproductive parts of the plant can be achieved only with the development of a sound photosynthetic structure during early periods of crop growth. Maximum total dry matter plant⁻¹ observed at 45 cm row spacings may be attributed to morphological characters like more plant height (96.17 cm), number of primary branches (9.51 plant⁻¹, Fig. 10), LA (105.1 dm² plant⁻¹), LAI (3.50, Fig. 12) and partly also to the increased nodule dry matter

(184.88 mg plant⁻¹) in 45 cm row spacing. This enhanced nodulation might have improved the nitrogen status of the plant at 45 cm row spacing leading to higher total dry matter production. These results are in conformity with the findings of Muhammad *et al.* (2000) for plant height and number of pods per plant in mung bean. Competition for light, CO₂, moisture and nutrients among closely spaced plants could have led to reduction in branch numbers, LA and plant dry weight. As higher plants react to stress of density by plastic response (Mureithi *et al.*, 2012).

The variations in number of pods plant⁻¹ could be attributed to the variations in number of productive branches plant⁻¹. Hence, medium spacing of 45 cm resulted in maximum number of primary branches plant⁻¹ and in turn was responsible for more number of productive parts. Further, less competition for natural resources with medium row spacing resulted in more reproductive parts compared to 30 and 60 cm row spacings. Row spacing will not have any significant effect on days to 50 per cent flowering and physiological maturity of pods (Ahmed *et al.*, 2010).

Haulm yield decreased significantly with increase in row spacing. Closer row spacing was recommended for the maximum forage production (Shivananda, 2005). Significantly lower haulm yield was observed in 60 cm row spacing (1791 kg ha⁻¹) than 30 and 45 cm (Fig. 3). This might be due to reduced growth and yield parameters (Rima and Nabam, 2013).

Harvest index is another useful parameter to assess the translocation efficiency in field crops. The seed yield is related to biological yield through harvest index (Muhammad, 2000). In the present study, higher harvest index was noticed in 30 and 45 cm row (30.17 and 29.98 %) spacing over 60 cm (28.98 %). This might be because of maximum vegetative growth and yield parameters in 30 and 45 cm row than in 60 cm (Fig. 3).

Evaluating the effects of row spacing and intra row spacing revealed that these factors had no significant effect on seed protein content of the genotypes because these are genotype characters which are genetically controlled rather than modification in planting geometry.

5.4 Performance of cowpea genotypes

Performance of the genotypes is governed by many factors, which individually or in combination to determine the yield potentiality. Optimum LAI coupled with higher photosynthetic activity may lead to higher biomass production and further by way of partitioning of dry matter, a genotype can yield better. Thus, identification of all such favourable yield and growth components and their integration in one genotype lead to its better performance over other genotypes.

In the present investigation, two genotypes namely DC 15 and C-152 were tested for their yield potentiality under different dates of sowing and planting geometry. DC 15 is a determinate type and C-152 is an indeterminate type. Both genotypes differed significantly with respect to duration. Variation in duration of genotypes might have occurred due to their difference in genetic trait (Abdur Rahman *et al.*, 2004).

In present study genotype DC 15 recorded significantly higher seed yield (1026 kg ha⁻¹) compared to genotype C-152 (887 kg ha⁻¹) (Fig. 3) which was 14 per cent higher as compared to C-152. Such significant differences in genotypes with respect to seed yield have been reported by Shivananda (2005) and Praveen Kumar *et al.* (2013) in cowpea, Soomro and Khan (2003) and Madhu (2013) in mung bean.

Genotype DC 15 was high yielding compared to C-152. Seed yield is governed by number of factors, which has direct or indirect impact. The factors responsible for high seed yield are the number of pods plant⁻¹, pod length, number of seeds pod⁻¹, test weight, seed weight plant⁻¹ and harvest index. The growth attributes like dry matter production has an indirect effect or influence on seed yield and in turn have their independence on different growth parameters namely plant height, number of primary branches, LA, LAI, LAD (Jakusko *et al.*, 2013). Genotype DC 15 recorded significantly higher yield attributing parameters than C-152.

Among the yield components seed weight was more closely associated with seed yield. Genotype DC 15 produced significantly higher seed weight (19.91 g) compared to genotype C-152 (18.70 g) (Fig. 5). This is in conformity with results earlier reported by Shivananda (2005), Agbogidi and Egbo (2012).

Numbers of pods are significantly higher in genotype DC 15 (12.99) compared to C-152 (12.37) (Fig. 4). With respect to pod length, number of seeds pod⁻¹ and test weight were also significantly higher in DC 15 (15.2 cm, 13.59 and 9.98 g respectively) (Fig. 6 and 7) (Plate 4 and 5)

than C-152. Genotype C-152 has registered lower seed yield due to less number of pods than DC 15. Thus, owing to integration of major favourable yield components such as number of pods, seed weight, test weight, genotype DC 15 produced higher seed yield compared to C-152 (Ugur Basaran *et al.*, 2011).

Differences observed in seed yield ha^{-1} and yield components can be traced back to differences in dry matter production and its accumulation in different plant parts. Genotype DC 15 produced higher total dry matter at all the growth stages (Fig. 9). At harvest, it has produced higher total dry matter ($43.15 \text{ g plant}^{-1}$) compared to C-152 ($39.18 \text{ g plant}^{-1}$). Similar results were reported by Shivananda (2005) and Addo-Quaye (2011) in cowpea, Madhu (2013) in mung bean. Higher translocation of photosynthates was possible due to better sink capacity of DC 15 than genotype C-152 as indicated by higher number of pods and seed weight plant^{-1} in DC 15. The better sink capacity might be attributed to the better dry matter production owing to better photosynthetic capacity of plant during both vegetative and reproductive phase of crop as shown by higher LA, LAI, LAD, canopy spread and determinate growth habit in DC-15. The present results are in conformity with earlier findings of Akbar Khan *et al.* (2010).

Genotypes differed significantly with respect to 50 per cent flowering. DC 15 took more number of days (57.3 days) for 50 per cent flowering than C-152 (55.85 days) (Fig. 8). This may be attributed to the fact that days to flowering in cowpea is varietal character which is genetically controlled. In DC 15 required less duration for physiological maturity of pods (84.3 days) where majority of pods matured at a time it might be because of accumulation of more agro climatic indices in short period due to its determinate character. C-152 registered long duration (93.5 days) for physiological maturity of pods and it has shown indeterminate character where pods will not mature at a time. Thus, higher partitioning efficiency of assimilates into reproductive parts resulted significantly higher seed yield in genotype DC 15 over C-152. The results were conformity with the findings of Ahmed *et al.* (2010) in cowpea opined that the varieties differed in 50 per cent flowering and genotype Buff was characterised by high seed weight and high productivity. Guriqbal Singh (2010) in mungbean reported that, the variety ML1265 attained lesser GDD, HTU and PTU and recorded higher grain yield over other varieties.

Differences in dry matter production were mainly because of various physiological factors during crop growth. Genotype DC 15 recorded higher LA, LAI and LAD at all the crop growth stages compared to C-152. At harvest, DC- 15 recorded significantly higher LAI (1.86) than C-152 (1.77) (Fig. 12). Similarly, DC 15 registered higher LAD (54.41 days) during 30 to 55 DAS than C-152 (52.8 days) (Fig. 11). At 55 DAS, LA was significantly higher in genotype DC 15 (101.7 dm^2) compared to C-152 (98.8 dm^2). Number of effective nodules and nodule dry weight will also significantly higher in case of DC 15 (Guriqbal Singh, 2012 in urdbean). These indicate that genotype DC 15 produced more dry matter weight as compared to C-152 (Fig. 9). Similar results were reported by Shivananda (2005) and Madhu (2013).

Percent harvest index (HI) is another important parameter to assess the translocation efficiency. Further it was also reported that, the yielding potentiality of a cultivar is associated with increased seed to stalk ratio (HI). Total dry matter was sole determinant of plant yield, but harvest indices of cultivars determine the efficiency of dry matter utilization. In the present investigation genotype DC 15 recorded maximum harvest index (29.98) than C-152 (29.43) (Fig. 3), which implies greater accumulation of dry matter toward seed development (Sah *et al.*, 2013).

Thus, it may be concluded that higher dry matter production and its efficient utilization of dry matter for seed production, genotype DC 15 out yielded C-152 and also DC 15 appears to be well adapted to the agro-ecological conditions of Dharwad.

5.5 Interaction effect of sowing windows and planting geometry on growth and yield of cowpea genotypes

5.5.1 Sowing windows and genotypes

The interaction effects of sowing windows and genotypes were significant with respect to seed yield, haulm yield and harvest index of cowpea (Fig. 3). Complimentary interaction of June second fortnight sowing along with DC 15 produced significantly higher seed yield (1239 kg ha^{-1}) as compared to other interaction effects of sowing windows and genotype. C-152 genotype with July second fortnight sowing recorded significantly lower seed yield (645 kg ha^{-1}). The higher seed yield in early sown crop (II fortnight of June) can also be attributed to higher values of yield components over the late sown crop (Soomro and Khan, 2003 and Madhu, 2013 in mung bean). Guriqbal Singh *et al.* (2010) in mungbean reported that interaction between date of sowing and genotypes for grain yield was significant.

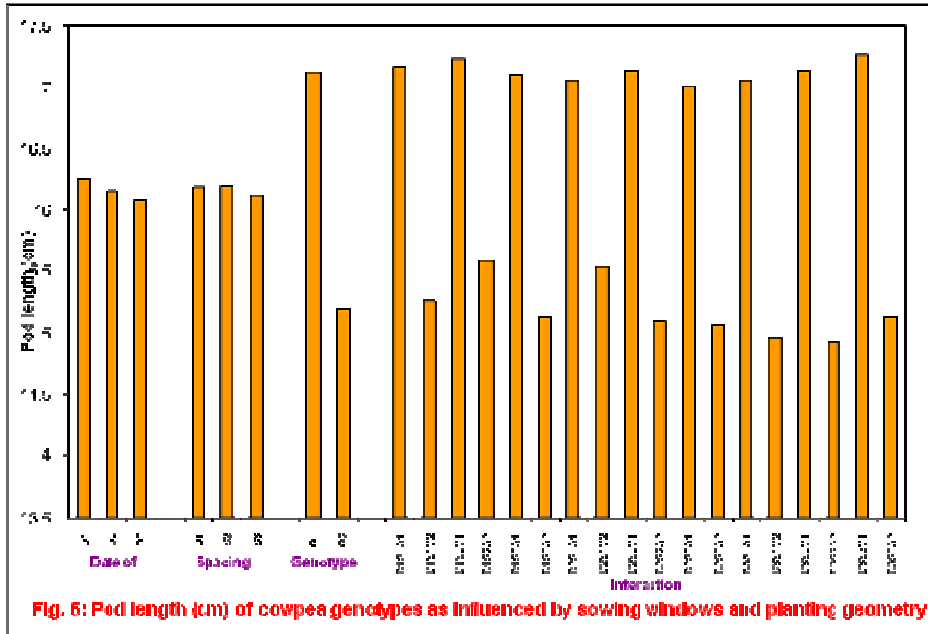


Fig. 6: Pod length (cm) of cowpea genotypes as influenced by sowing windows and planting geometry

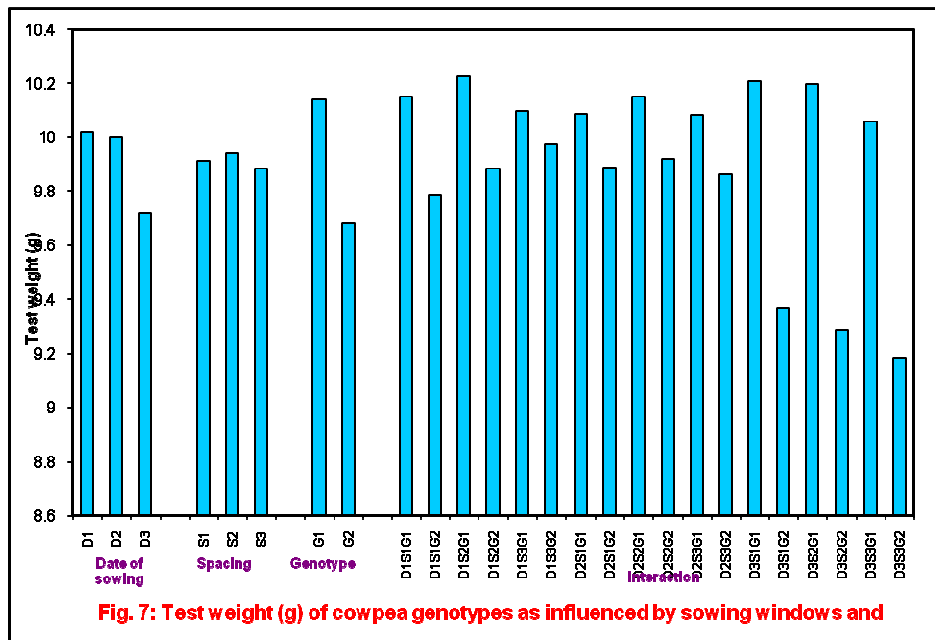


Fig. 7: Test weight (g) of cowpea genotypes as influenced by sowing windows and planting geometry



Plate 3. Crop growth in different planting geometry

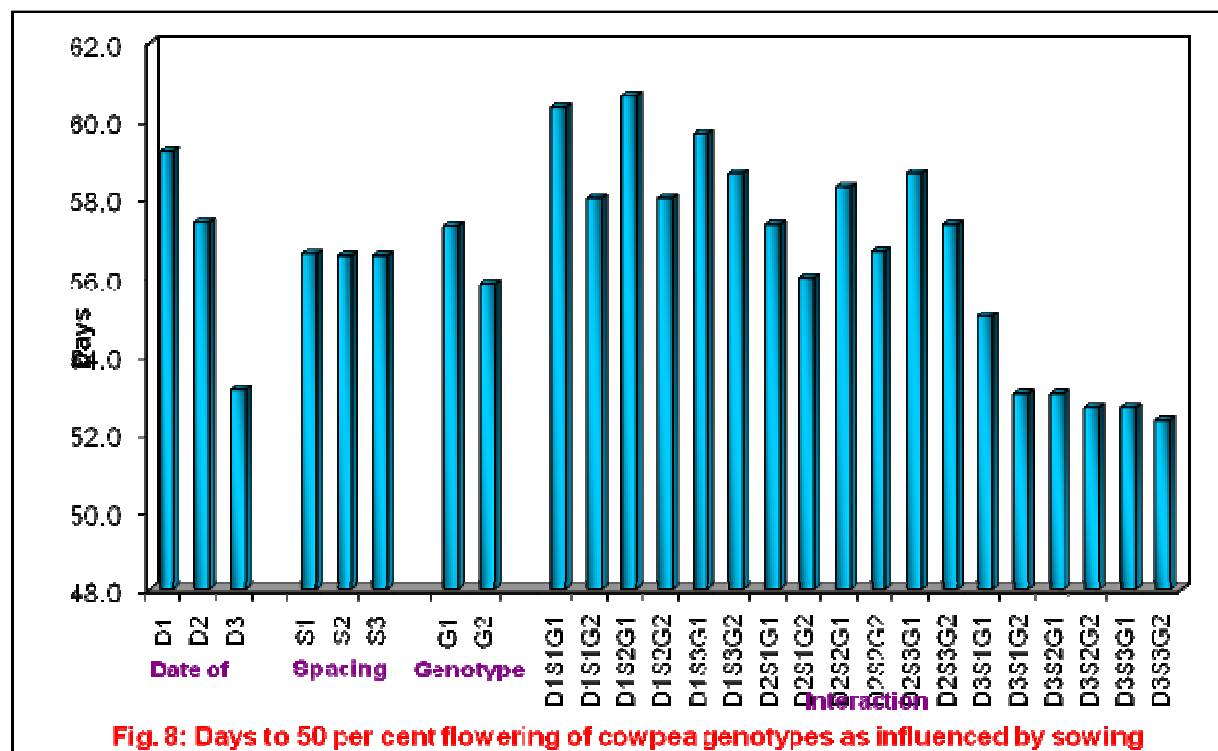


Fig. 8: Days to 50 per cent flowering of cowpea genotypes as influenced by sowing windows and planting geometry

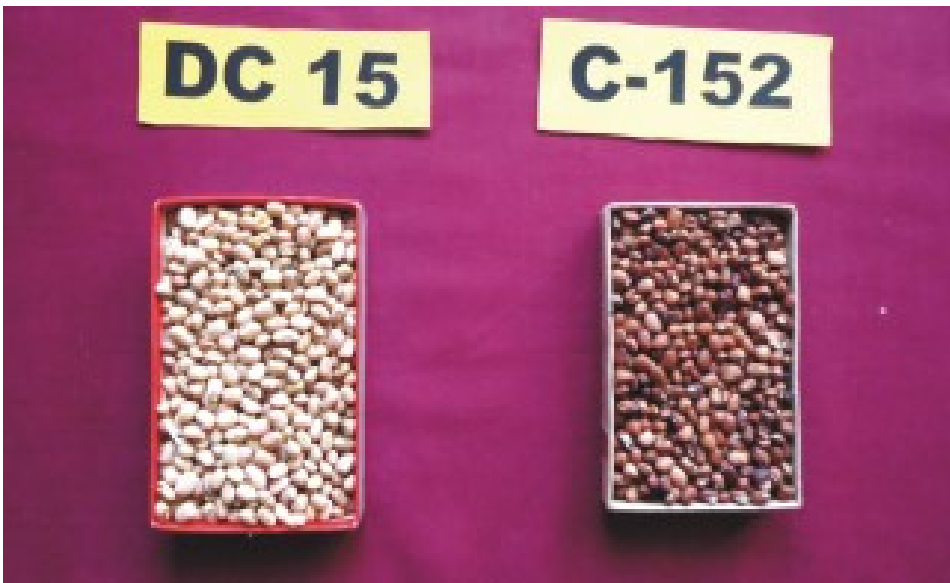
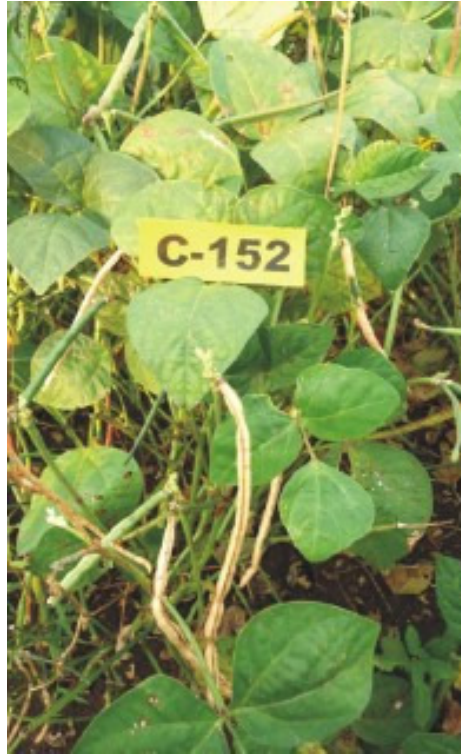


Plate 4. Pod and seed characters in different genotypes

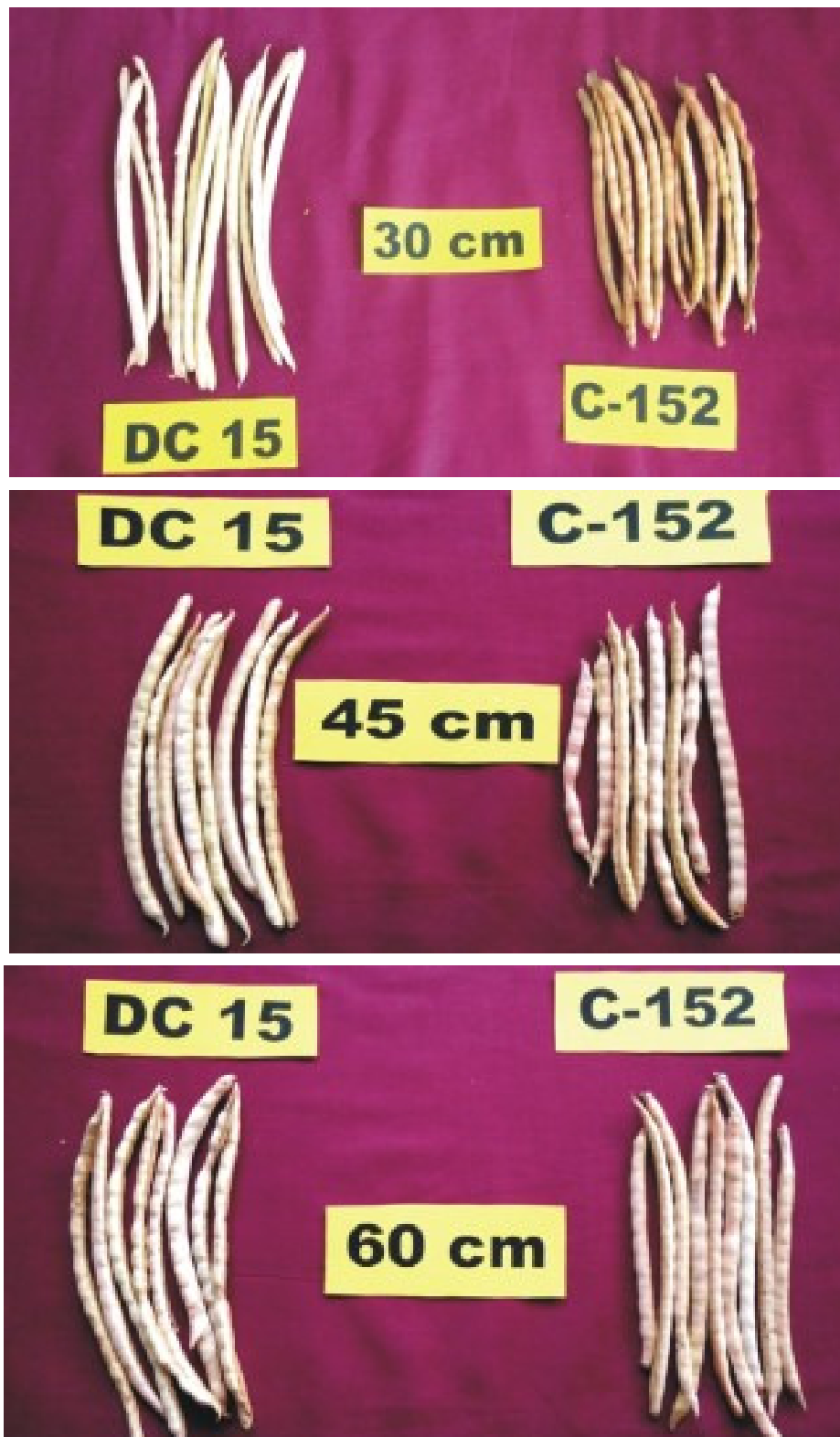


Plate 5. Pod length variation in DC 15 and C-152 cowpea genotypes

The increase in yield might be due to increase in yield attributing characters like number of pods plant⁻¹ (15.54), seeds pod⁻¹ (15.80), pod length (17.17 cm) and seed weight plant⁻¹ (21.41 g) contributed to the higher seed yield (Fig. 3). But there is no significant difference was observed for all these yield attributing characters due to interaction effects of sowing windows and genotypes. Similar findings were reported in mungbean by Soomro and Khan (2003), Sadeghipour. (2008). The VC-4152 variety sown on June 29th recorded the higher seed yield (134.7 g m⁻²) mainly due to increased number of pods plant⁻¹. While the Pusa1973 variety sown on May 30th recorded the lowest seed yield (60.33 g m⁻²) which might be due to decreased number of pods plant⁻¹ and 1000-seed weight.

The various yield components which lead to significant yield differences could be traced back to variation in dry matter produced as indicated by total dry matter production plant⁻¹ (Fig. 9). Many of the growth characters and yield attributes of the plant have their contribution to the seed yield. It is an end product of various physiological processes of plant and is the reflection of production of total dry matter plant⁻¹ (Rathore *et al.*, 2010).

5.5.2 Planting geometry and genotypes

The seed yield of cowpea significantly influenced by positive interaction of planting geometry and genotypes (Fig. 3). Among the treatment combinations, variety DC 15 sown in 45 cm row spacing recorded significantly higher seed yield (1140 kg ha⁻¹) over other treatment combinations. However it was on par with the crop sown in 30 cm row spacing with genotype DC 15. The lower seed yield of cowpea was noticed in crop sown at 60 cm row spacing with C-152 (724 kg ha⁻¹). Similar findings were observed by Shivananda (2005) in cowpea.

The higher seed yield in genotype DC 15 with 45 cm row spacing can also be attributed to higher values of yield components over 60 cm row spacing. There was increase in the values of yield attributing characters like number of pods plant⁻¹ (13.93), number of seeds pod⁻¹ (15.47), pod length (17.17 cm), seed weight plant⁻¹ (20.80 g) and test weight (10.19 g) in DC 15 genotype with 45 cm row spacing compared to DC 15 genotype with 60 cm row spacing (11.31, 11.93, 13.94 cm, 18.37 g and 9.88 g respectively). However there is no significant difference was observed for all these growth characters due to interaction effects of planting geometry and genotypes (Fig. 4, 5, 6, 7).

5.5.3 Sowing windows and planting geometry

Sowing windows and planting geometry have significant influence on growth of cowpea. Total dry matter production plant⁻¹ (24.40 g plant⁻¹) at 55 DAS was significantly higher in 45 cm row spacing sown at second fortnight of June (Fig. 9), this might be due to sufficient rainfall during germination and crop growth period which has helped for better soil moisture availability throughout the crop growth period.

The higher dry matter accumulation achieved with the development of sound vegetative growth parameters are mainly due to increase in plant height (64.3 cm), number of primary branches (8.9), LA (114.1 dm²), LAI (3.80) at 55 DAS and LAD (62.9 days) at 30 to 55 DAS (Fig. 11 and 12). The improvement in growth indices with different treatments is attributed mainly to genetic constituent of the genotype and high rainfall during July which helps in availability of sufficient soil moisture throughout crop growth period and escape of plant from moisture stress. These results are in agreement with the previously findings reported by many workers (Abdur Rahman *et al.*, 2004 in mungbean, Famara Massaly (1991) and Rima and Nabam (2013) in cowpea). They reported that date of sowing and plant population will have significant effects on growth and yield attributing characters.

5.6 Quality parameters

In the present investigation, there was no significant difference was observed in grain protein content due to the sowing windows and planting geometry (Fig. 13).

Between the cowpea genotypes, significantly higher grain protein content was recorded in DC 15 (24.36 %) over C-152 (21.33 %). None of the interactions effects were significant. These results are in conformity with findings of Madhu (2013) reported that seed protein content is a genotype character which is genetically controlled. Azarakhsh *et al.* (2007) opined that the grain protein content was not affected by different row and intra row spacings.

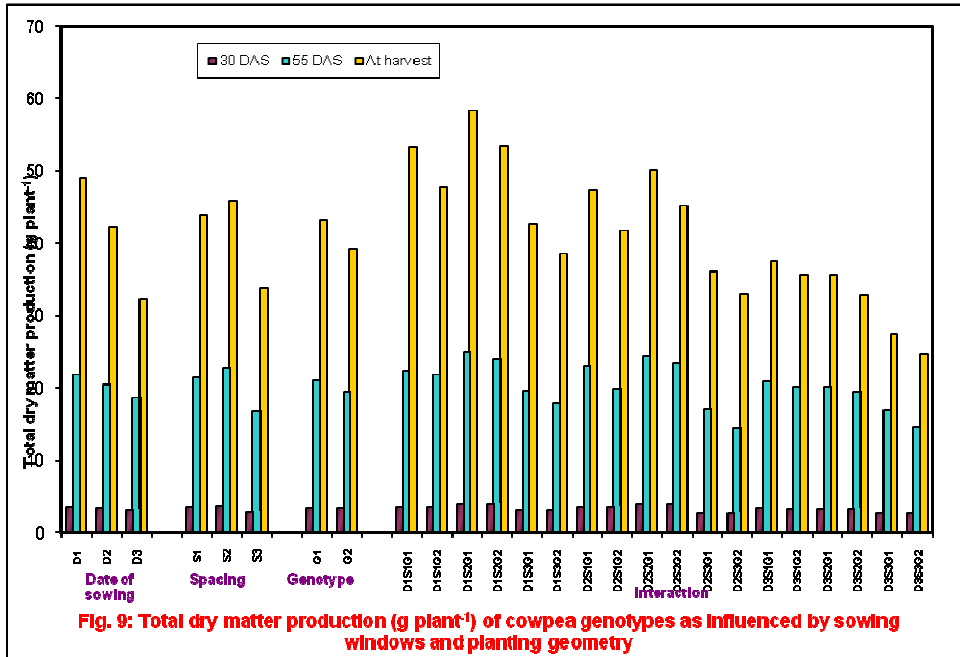


Fig. 9: Total dry matter production (g plant⁻¹) of cowpea genotypes as influenced by sowing windows and planting geometry

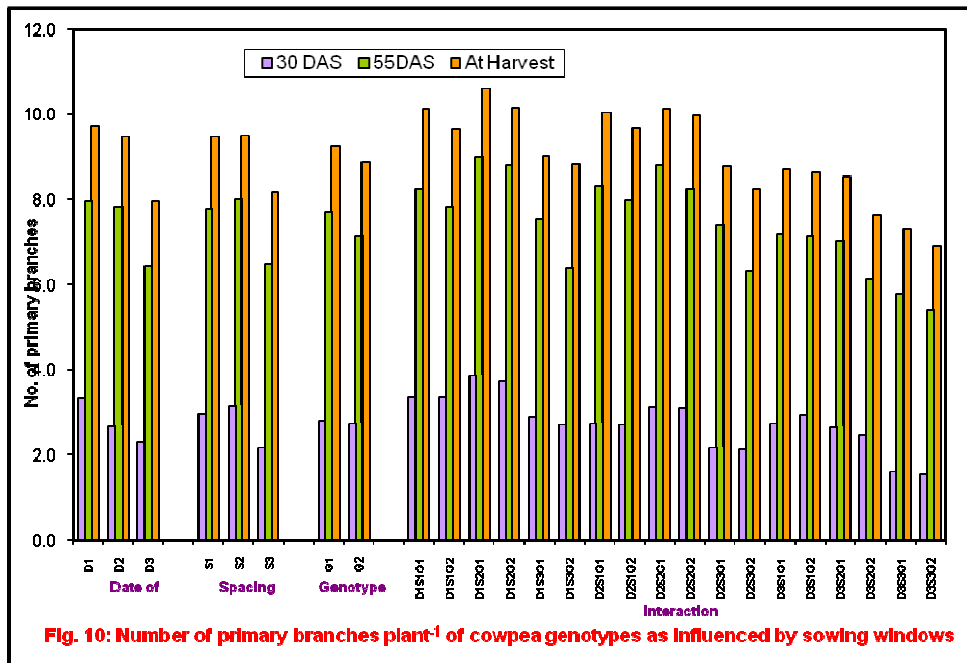


Fig. 10: Number of primary branches plant⁻¹ of cowpea genotypes as influenced by sowing windows and planting geometry



Fig 11: Leaf area duration (days) of cowpea genotypes as influenced by sowing windows and planting geometry

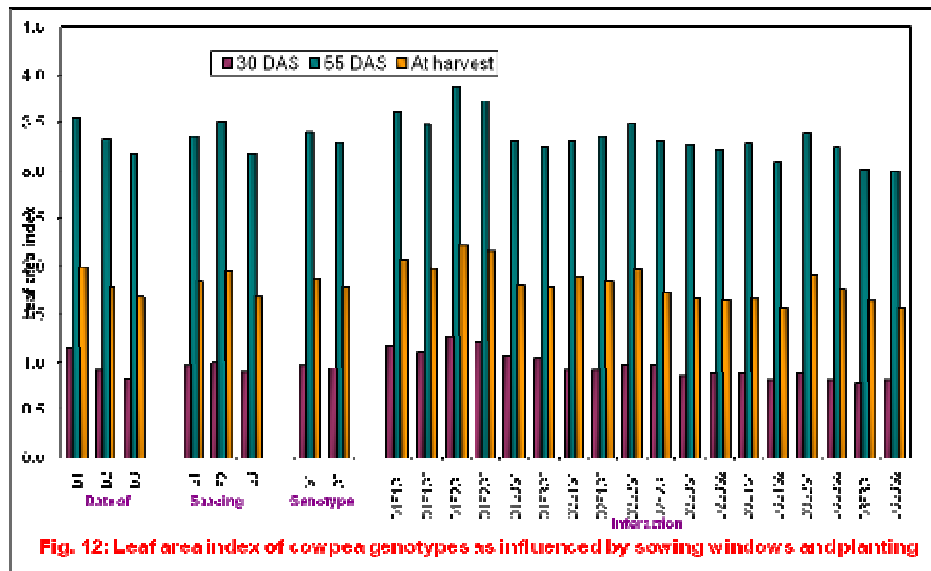


Fig. 12: Leaf area index of cowpea genotypes as influenced by sowing windows and planting geometry

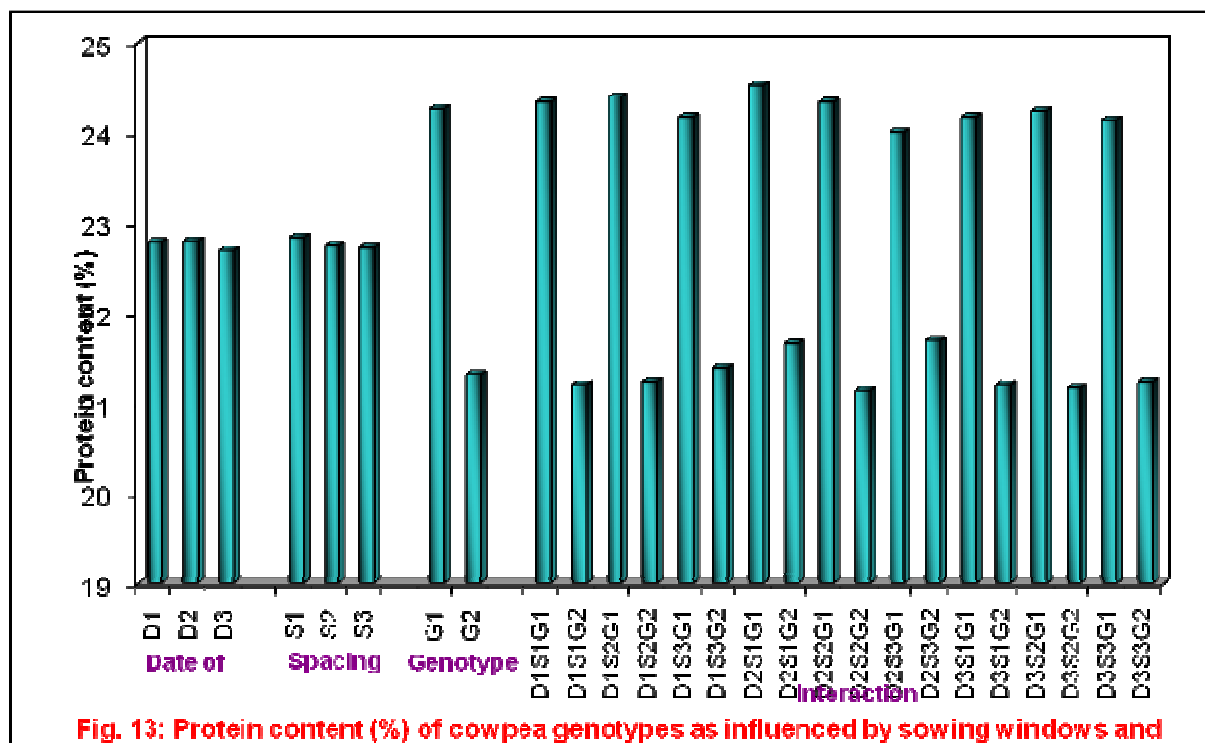


Fig. 13: Protein content (%) of cowpea genotypes as influenced by sowing windows and planting geometry

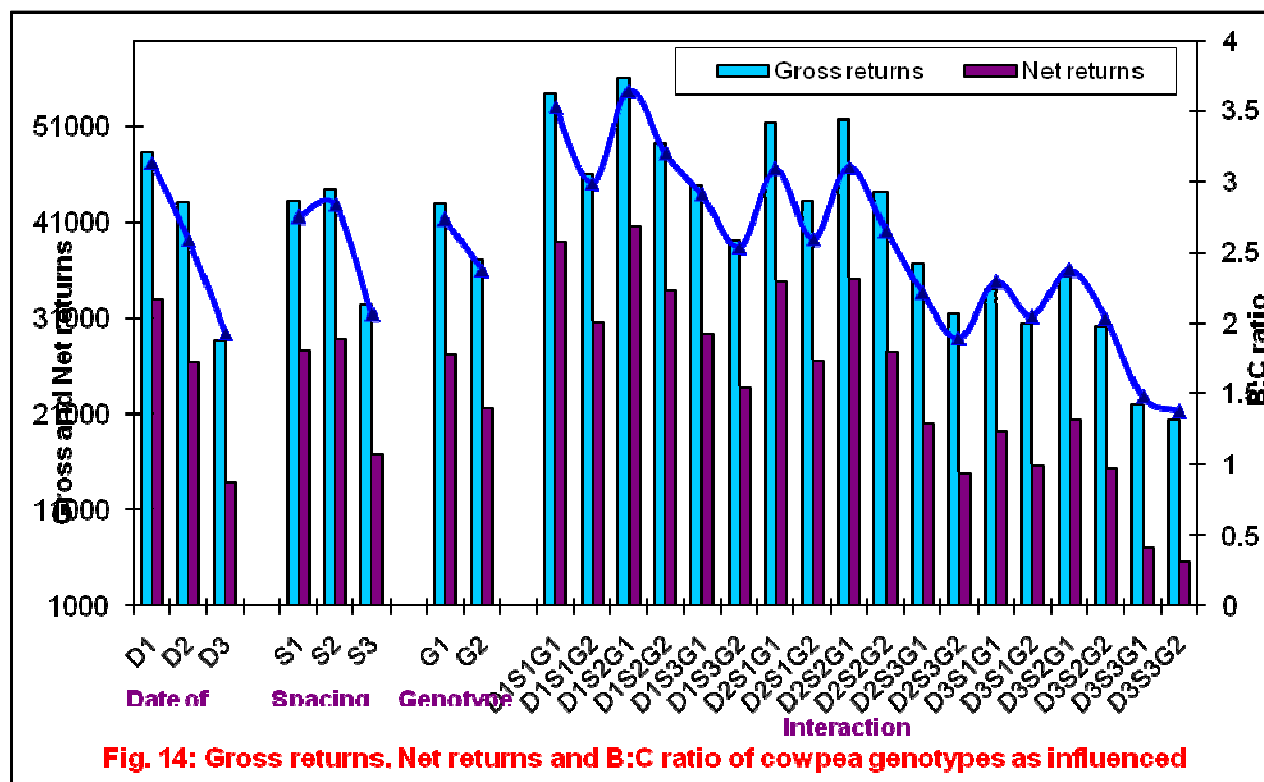


Fig. 14: Gross returns, Net returns and B:C ratio of cowpea genotypes as influenced by sowing windows and planting geometry

5.7 Economics

The price of inputs and farm produce change from time to time, place to place and treatment to treatment. Hence it is important to know the economics of each field experiment. The gross return, net return and benefit cost ratio differed significantly due to various treatments (Fig. 14).

Among the different dates of sowing, second fortnight of June sown crop recorded significantly higher gross return ($\text{₹ } 48,230 \text{ ha}^{-1}$), net return ($\text{₹ } 32,816 \text{ ha}^{-1}$) and benefit cost ratio (3.13) over others. The higher net return obtained in II fortnight of June might be attributed to higher yield and reduced cost of cultivation. These results in agree with the findings of Madhu (2013). The genotype DC 15 recorded significantly higher gross return ($\text{₹ } 42,865$) net return ($\text{₹ } 27,238$) and benefit cost ratio (2.73) over C-152 ($\text{₹ } 37,094$, $\text{₹ } 21,468$ and 2.37 respectively).

Net return was significantly higher in DC 15 sown on second fortnight of June ($\text{₹ } 36,272 \text{ ha}^{-1}$). However, the lowest net return was realized by C-152 genotype sown on second fortnight of July ($\text{₹ } 12,148$). This is mainly attributed to lower gross return and higher cost of cultivation realized in this treatment combination. Lowest gross return recorded with II fortnight of July were due to lower yield which perhaps could be attributed to higher biotic (pod borer and rust) (Appendix IV) and abiotic stresses (moisture stress).

The net return of cowpea was significantly influenced by planting geometry and genotypes. Among the treatment combinations, variety DC 15 sown in 45 cm row recorded significantly higher net return ($\text{₹ } 28,751 \text{ ha}^{-1}$) over other treatment combinations. However it was on par with DC 15 sown on 30 cm row ($\text{₹ } 27,552 \text{ ha}^{-1}$). The lower net return of cowpea noticed in genotype C-152 sown in 60 cm row spacing ($\text{₹ } 16,755 \text{ ha}^{-1}$). This is mainly attributed to lower gross return due to less grain yield and higher cost of cultivation realized in this treatment combination (Shivananda, 2005).

Practical utility

From the results of present investigation, the following inferences of practical importance can be drawn.

1. Genotype DC 15 can be better adopted in Northern Transitional Zone (Zone-8) of Karnataka during *khariif* season, mainly because of its determinate growth habit, high seed yielding ability (1026 kg ha^{-1}), better quality of seed (creamy white with bold seeds) and higher protein content (24.26 %).
2. High seed yield of genotype DC 15 can be obtained by early sowing (second fortnight of June) with 45 cm planting geometry.

Future line of work

The findings of the present investigation have led to the identification of following thrust areas for future research.

1. Response of cowpea genotypes to growth retardants for suppression of excessive vegetative growth and better partitioning of dry matter for increased seed yield needs to be studied.
2. There is a need to evaluate the genotype DC 15 under different cropping systems and integrated nutrient managements.

SUMMARY AND CONCLUSIONS

A field experiment was carried out to study the “Response of Cowpea Genotypes to Sowing Windows and Planting geometry Under Northern Transitional zone of Karnataka” at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during *kharif* 2013. The experiment was laid out in Split plot design with three main plots (dates of sowing *i.e.*, I fortnight of June, I and II fortnight of July), three sub plots (spacing *i.e.*, 30 cm, 45 cm and 60 cm row) and two sub sub plots which comprise of genotypes (DC 15 and C-152). This study has brought out some useful results and is summarized as below

- ❖ In the present investigation early sowing (second fortnight of June) of cowpea recorded significantly higher seed yield (1155 kg ha⁻¹) over late sown condition (second fortnight of July). The increase was 41 per cent higher in second fortnight of June.
- ❖ Early sowing (second fortnight of June) resulted in significantly higher yield attributes like number of pods plant⁻¹ (15.22) and seed weight plant⁻¹ at harvest.
- ❖ Growth attributes like plant height, number of primary and secondary branches, leaf area, leaf area index, LAD, number of root nodules and dry weight, total dry matter production, were also significantly higher with the early sowing (second fortnight of June) as compared to other dates of sowing.
- ❖ At harvest, 45 and 30 cm row spacings recorded significantly higher plant height, number of branches, leaf area duration, total dry matter production, number of pods and seed weight plant⁻¹.
- ❖ Significant differences due to row spacings were observed in leaf area and leaf area index at 30, 55 DAS and at harvest. Maximum leaf area was obtained with row spacing of 45 cm, while minimum leaf area plant⁻¹ was observed in 60 cm. Leaf area index decreased significantly with increase in row spacing and decrease in intra row spacing.
- ❖ The total dry matter production was significantly higher with medium (45 cm) row spacing at 30, 55 DAS and at harvest (3.67, 22.71 and 45.9 g plant⁻¹, respectively) over narrow row spacing of 30 cm and wider row spacing of 60 cm.
- ❖ 45 and 30 cm row spacing recorded significantly higher yield attributing parameters like number of pods plant⁻¹ (13.59 and 13.43) and seed weight plant⁻¹ (19.96 and 19.99 g respectively) over 60 cm row spacing. But there is no significant difference was observed on pod length, number of seeds pod⁻¹ and test weight due to variation in row spacings.
- ❖ Consequent upon improved growth and yield attributes the significantly higher seed and haulm yield (1062 and 2373 kg ha⁻¹, respectively) was recorded with 45 cm than 60 cm row however it was on par with 30 cm row (1034 and 2296 kg ha⁻¹ respectively). Harvest index also significantly higher in 45 and 30 cm row than 60 cm row spacing.
- ❖ Irrespective of sowing windows and planting geometry the two cowpea genotypes belonging to different maturity group differed significantly in their growth and yielding abilities. The two genotypes belonged to different maturity groups. Between the genotypes DC 15 took 57 days to 50 per cent flowering while, C-152 took less time (55.8 days) where as DC 15 took less days to physiological maturity of pods than C-152 because of its determinate growth habit.
- ❖ Maximum plant height (91.6 cm) at harvest was obtained with DC 15 and it was minimum with C-152 (87.8 cm). Maximum number of primary branches were (9.3) observed with DC 15 compared to C-152 (8.9).
- ❖ Leaf area and leaf area index differed significantly between genotypes and DC 15 recorded significantly higher leaf area and leaf area index than C-152 at all the crop growth stages.
- ❖ DC 15 recorded significantly higher total dry matter production at all the stages of crop growth (3.31, 21.03 and 43.15 g at 30, 55 DAS and at harvest, respectively) over C-152.
- ❖ All the yield attributing parameters (number of pods plant⁻¹, pod length, number of seeds pod⁻¹, seed weight plant⁻¹, test weight) were significantly higher with DC 15 than with C-152.
- ❖ Genotype DC 15 registered significantly higher seed yield (1026 kg ha⁻¹) over C-152 (887 kg ha⁻¹). Similarly, haulm yield and harvest index was also higher with DC 15 (2279 kg ha⁻¹ and 29.98 respectively) compared to C-152 (2027 kg ha⁻¹ and 29.43 respectively).

- ❖ Sowing windows and genotype interactions have significant influence on seed yield of cowpea. Early sowing (second fortnight of June) of cowpea genotype DC 15 recorded higher seed yield, haulm yield and per cent harvest index (1239 and 2647 kg ha⁻¹, 30.86 respectively). Significantly lower seed yield (645 kg ha⁻¹) was recorded with late sowing of cowpea genotype C-152 (second fortnight of July).
- ❖ Planting geometry and genotype interactions also have significant effects on seed yield. Sowing of cowpea genotype DC 15 in 45 cm row recorded significantly higher seed yield and haulm yield (1140 and 2528 kg ha⁻¹ respectively) compared to other treatment combinations. However, lower values for the above yield parameters were recorded with C-152 genotype sown in 60 cm row spacing (724 and 1699 kg ha⁻¹).
- ❖ Dates of sowing and planting geometry had influence on growth of cowpea at 55 DAS. Early sowing (second fortnight of June) of cowpea genotypes in 45 cm row spacing recorded significantly higher values for different growth parameters analyzed like plant height (64.3 cm), number of primary branches (10.4), number of secondary branches (2.3), leaf area (114.1 dm²), leaf area index (3.80) and total dry matter production (24.4 g plant⁻¹). Significantly lower values for the above mentioned growth attributes recorded with C-152 with 60 cm row spacing.
- ❖ Significantly higher grain protein content (24.26 %) was recorded in genotype DC 15 as compared to C-152 (21.33 %).
- ❖ Higher net return was recorded with DC 15 sown during second fortnight of June (₹ 36272 ha⁻¹). The higher benefit cost ratio was also observed with DC 15 sown in second fortnight of June (3.35) over other treatment combinations.

REFERENCES

- Abdelbagi, M., Ismail and Antony, E. H., 2000, Semi dwarf and standard height cowpea response to row spacing in different environment. *Crop Sci.*, 40(6): 1618-1628.
- Abdur Rahman, S. M. D., Hasan Kabir, M. D., Mahfuza Begum and Abdus Salam, 2004, Yield performance of mungbean as affected by planting date variety and plant density. *J. Agron.*, 3(1): 18-24.
- Addo-Quaye, A. A., Darkwa, A. A. and Ampiah, M. K. P., 2011, Performance of three cowpea (*Vigna unguiculata* L. Walp) varieties in two agro-ecological zones of the central region of Ghana I: dry matter production and growth analysis. *ARP. J. Agril. and Biol. Sci.*, 6(2): 1-9.
- Agbogidi, O. M. and Egho, E. O., 2012, Evaluation of eight varieties of cowpea (*Vigna unguiculata* L. Walp) in Asaba agro-ecological environment, Delta state, Nigeria. *European J. Sustain. Devt.*, 1(2): 303-314.
- Ahmed El Naim, M., Abdelrhim Jabereldar, A., Salaheldeen Ahmed, E., Feisal Ismaeil, M. and Elshiekh Ibrahim, A., 2012, Determination of suitable variety and plants per stand of cowpea (*Vigna unguiculata* L. Walp) in the sandy soil, Sudan. *Adv. Life Sci.*, 2(1): 1-5.
- Ahmed El Naim, M., Amgad Hagelsheep, M., Muatasim Abdelmuhsin, S., Abdu Abdalla, E., 2010, Effect of intra-row spacing on growth and yield of three cowpea (*Vigna unguicula* L. Walp) varieties under rainfed. *Res. J. Agric. Biol. Sci.*, 6(5): 623-629.
- Akbar Khan, Abdul Bari, Sajid Khan, Nazeer Hussain Shah and Islam Zada, 2010, Performance of cowpea genotypes at higher altitude of NWFP. *Pak. J. Bot.*, 42(4): 2291-2296.
- Anil Kumar and Reena, 2007, Assesment of grain yield potential of mungbean in shivalik foothills of India. *J. Agron.*, 6(3): 476-479.
- Anonymous, 1991a, Annual Report, Univ. of Agril. Sci., Bangalore, Pp. 122-126.
- Anonymous, 1991b, Annual Report, Univ. of Agril. Sci., Bangalore, Pp. 126-127.
- Anonymous, 1994. Annual Progress Report, Agriculture Research Station, Bheemarayanagudi, Univ. Agril. Sci., Dharwad.
- Anonymous, 2001, Annual Report for 2000-01. Southern Transitional Zone (VII), Univ. Agril. Sci., Bangalore.
- Anonymous, 2009, Production year book, FAO, p. 28.
- Anonymous, 2011, Vision 2030, Indian Council of Agricultural Research, New Delhi, India.
- Anonymous, 2012, Report of export group on pulses. Department of Agriculture and co-operation. GOI, Ministry of Agriculture, New Delhi.
- Anonymous, 2013, State Agriculture profile, KSDA, Karnataka.
- Asghar Malik, M., Farrukh Saleem, M., Asghar Ali and Ahmad Faraz Ishaq, 2006, Effects of sowing dates and planting patterns on growth and yield of mungbean. *J. Agric. Res.*, 44(2): 139-146.
- Asthana, A. N., 1998, Pulse crops research in India. *Indian J. Agril. Sci.*, 68(2): 448-452.
- Azarakhash, T. J., Amir, F. M., Addollah, H., Shahin, Y. and Sahab, R., 2007, Row spacing and inter row spacing effects on some agro-physiological traits of two common bean (*Phaseolous vulgaris* L.) cultivars. *Pak. J. Biol. Sci.*, 10(24): 4543-4546.
- Babalola, O., 1980, Water relations of three cowpea cultivars (*Vigna unguiculata*, L.). *Plant and Soil*, 56: 59-69.
- Birari, D. S., Birari, S. P. and Jamadagni, B. M., 1993, Stability analysis of promising genotypes of cowpea (*Vigna unguiculata*). *Indian J. Agril. Sci.*, 63(2): 103-106.
- Choudhary, M. and Bovasky, D. G., 2001, Plant stand density and row configuration effect on production of Texas pinkeye hull cowpea. *Texas J. Agril. Nat. Resou.*, 14: 104-111.
- Daljit Singh, Sandhu, K. S., Saimbhi, M. S. and Singh, D., 1992, Effect of plant spacing on the pod yield of cowpea. *J. Res. Punjab Agril. Univ.*, 29(3): 345-346.

- Degri, M. M., Sharah, H. A. and Dauda, Z., 2012, Effects of intercropping pattern and planting date on the performance of two cowpea varieties in Dalwa, Maiduguri, Nigeria. *J. Environ. Issues and Agric. in Develop. Countries*, 4(3): 36-42.
- Ekpo, I. A., Agbor, R. B., Osuagwu, A. N., Okpako, E. C. and Ekanem, B. E., 2012, Evaluation of eight cowpea (*Vigna unguiculata* L. Walp) species for yield and associated traits. *Int. J. Pure Appl. Sci. Technol.*, 12(2): 1-7.
- Famara Massaly, 1991, Effects of planting date, seed size-density and plant population on growth and reproduction of two cultivars of cowpea. *M. Sc. (Agri.) Thesis*, Mississippi State Univ., Bombay.
- Fraz, R. A., Alias, M. A., Bakhsh, H. A., 2006, Effect of sowing dates and planting patterns on growth and yield of mungbean (*Vigna radiata* L.) cv. M-6. *Int. J. Agric. Biol.*, 8(3): 363-365.
- Gomez, K. M. and Gomez, A. A., 1984, *Statistical Procedures for Agril. Res.*, Edition 2, John Wiley, New York.
- Guriqbal Singh and Sekhon, H. S., 2007, Effect of date of sowing on growth and yield of mungbean varieties during *kharif* season. *J. Food Leg.*, 20(1): 59-61.
- Guriqbal Singh, Hari Ram, K. K., Sekhon, H. S., Gill and Veena Khanna, 2012, Effect of time of planting on nodulation growth and seed yield of *kharif* urdbean genotypes. *J. Food Leg.*, 25(2): 125-127.
- Guriqbal Singh, Sekhon, H. S., Hari Ram, K. K., Gill and Poonam Sharma, 2010, Effect of time of sowing on nodulation, growth, thermal requirement and grain yield of *kharif* mungbean genotypes. *J. Food Leg.*, 23(2): 132-134.
- Ihsanullah, Amanullah Jan, Fazal Hayat, T., Ijaz Ahmad, K. and Naeem Khan, 2002, Effect of sowing dates on yield and yield components of mashbean varieties. *Asian J. Plant Sci.*, 1(6): 622-624.
- Ihsanullah, Fazal Hayat, T., Habib Akbar, Abdul Basir and Noor Ullah, 2002, Effect of row spacing on agronomic traits and yield of mungbean (*Vigna radiata* L. Wilczek). *Asian J. Plant Sci.*, 1(4): 328-329.
- Jackson, M. L., 1967, *Soil Chemical Analysis*, Prentice Hall of India Pvt. Ltd., New Delhi, India.
- Jackson, M. L., 1973, *Soil Chemical Analysis*, Prentice Hall of India Pvt. Ltd., New Delhi, India.
- Jadhav, A. G., Shinde, S. H. and Pol, P. S., 1995, Growth and yield of cowpea varieties as influenced by seedling dates. *J. Maharashtra Agril. Univ.*, 20(5): 295-296.
- Jakusko, B. B., Anasunda, U. I. and Mustapha, A. B., 2013, Effect of inter-row spacing on some selected Cowpea (*Vigna unguiculata* L. Walp) varieties in Yola, Adamawa State, Nigeria. *J. Agric. Veter. Sci.*, 2(3): 30-35.
- Kabir, M. H. and Sarkar, M. A. R., 2008, Seed yield of mungbean as affected variety and plant spacing in *kharif* season. *J. Bangladesh Agril. Univ.*, 6(2): 239-244.
- Kaki Ngodi, F., Ibrahim Dauda, B. and Wasinata Tizhe, 2010, Effect of sowing date on yield and yield components of cowpea (*Vigna unguiculata* L. Walp) in mubi north local government area, Adamawa State, Nigeria. *New York Sci. J.*, 3(11): 98-102.
- Kalpana, 2000, Morpho-physiological traits associated with productivity in cowpea (*Vigna unguiculata* L. Walp). *M. Sc. (Agri.) Thesis*, Univ. of Agril. Sci, Dharwad, India.
- Kamannavar, P. Y., Vijaykumar, A. G., Revanappa, S. B., Ganajaxi, M., Arunkumar, Kuchanur, P. H. and Salimath, P. M., 2011, Genotype x Environment interaction in mungbean (*Vigna radiata* L. Wilczek) cultivars grown in different agro-climatic zones of Karnataka. *Electron. J. Plant Breed.*, 2(4): 501-505.
- Kay, W., 1979, Guidelines for the production of cowpea (*Vigna unguiculata*). *Field Crop Abstracts*, 27: 301-312.
- Krishna Kurubetta, D., 2006, Effect of time of sowing, spacing and seed rate on seed production potentiality and quality of fodder cowpea (*Vigna unguiculata* L. Walp). *M. Sc. (Agri.) Thesis*, Univ. Agril. Sci., Dharwad, India.

- Lemma, G., Worku, W. and Woldemichael, A., 2009, Moisture and planting density interactions affect productivity in cowpea. *J. Agron.*, 8(4): 117-123.
- Madhu, G., 2013, Response of mungbean (*Vigna radiata* L. Wilczek) genotypes to dates of sowing and foliar nutrition in *kharif* season. *M. Sc. (Agri.) Thesis*, Univ. Agril. Sci., Dharwad, India.
- Mohapatra, S. C., Patra, A. K., Senapati, S. C. and Mishra, A., 1996, Response of blackgram (*Phaseolus mungo* L.) varieties to phosphorus. *Crop Res.*, 11(5): 165-168.
- Muhammad, N. I., Badar, N. S. and Muhammad, Z. Y. H., 2000, Effect of different planting densities on yield and yield components of mungbean (*Vigna radiata* L.). *Pak. J. Biol. Sci.*, 3(12): 2039-2040.
- Mureithi, D. M., Onyango, M. O. A., Jeruto, P. and Gichimu, B. M., 2012, Response of French bean (*Phaseolus vulgaris* L.) to intra row spacing in maseno division, Kenya. *J. Appl. Sci.*, 12(1): 96-100.
- Nargis Jahan and Golam Adam, M. M., 2012, Growth and yield performance of Bari mung-5 under different time of sowing. *J. Bangladesh Acad. Sci.*, 36(2): 227-231.
- Nirmal, Rajkumar, Kalloo, G. and Kumar, R., 2001, Diet versatility in cowpea (*Vigna unguiculata*) genotypes. *Indian J. Agril. Sci.*, 71(2): 598-601.
- Nwokolo, E. and Smart, J., 1996, *Food and feed leg. and oil seeds*. Chapman and Hall, London, p. 229.
- Olotuah, O. F. and Fadare, Z. O., 2012, Growth morphology and seed quality variation among five indigenous varieties of cowpea. *Int. J. Agric. Sci.*, 2(6): 546-549.
- Patel, B. V., Parmar, B. R., Parmar, S. B. and Patel, S. R., 2011, Effect of different spacings and varieties on yield parameters of cowpea. *Asian J. Hort.*, 6(1): 56-59.
- Patil, F. M. and Patil, L. R., 1991, Response of greengram varieties to phosphorus and rhizobium inoculation. *Indian J. Agron.*, 36(2): 295-297.
- Patil, N. K. B., Kamannavar, P. Y. and Biradar, D. P., 1991, Performance of cowpea varieties at two inter row spacings. *J. Maharashtra Agril. Univ.*, 16(1): 111-112.
- Piper, C. S., 1966, *Soil and Plant Analysis*, Hands Publishers, Bombay, p.368.
- Power, J. F., Willis, W. O., Grunes, D. L. and Reichman, G. A., 1967, Effect of soil temperature, phosphorus and plant age on growth analysis in barley. *Agron. J.*, 59: 231-234.
- Praveen Kumar, K., Nathish Kumar, R., Muneeswari, Nagajothi, T., Rajesh Lamror and Usha Kumari, R., 2013, Morphological and genetic variation studies in cowpea genotypes (*Vigna unguiculata*). *Leg. Res.*, 36(4): 351-354.
- Rajesh kumar, Yadav, B. D., Joon, R. K. and Kumar, R., 1997, The effect of intra and inter-row spacing and varieties on the seed yield of cowpea. *Int. J. Trop. Agric.*, 15(4): 233-236.
- Ram, J., Ansari, M. M. and Sharma, 1994, Relative performance of cowpea genotypes in rainfed condition of Andaman and their genetic parameter analysis for seed yield. *Indian J. Pulse Res.*, 7(1): 72-75.
- Rasul, F., Cheema, M. A., Sattar, A., Saleem, M. F. and Wahid, M. A., 2012, Evaluating the performance of three mungbean varieties grown under varying inter-row spacing. *J. Animal & Plant Sci.*, 22(4): 1030-1035.
- Rathore, S. S., Dashora, L. N. and Kaushik, M. K., 2010, Effect of sowing time and fertilization on productivity and economics of urdbean genotypes. *J. Food Leg.*, 23(2): 154-155.
- Rehman, A., Khalil, S. K., Nigar, S., Rehman, S., Haq, I., Akhtar, S., Khan, A. Z. and Shah, S. R., 2009. Phenology plant height and yield of mungbean varieties in response to planting date. *Sarhad J. Agric.*, 25(2): 147-151.
- Reza Monem, Seied Mehdi, M. and Ali Ahmadi, 2012, Investigation of row orientation and planting date on yield and yield components of mungbean. *Ann. Biol. Res.*, 3(4): 1764-1767.

- Rhandzu, P. S., 2007, Effects of planting date and location on phenology yield and yield components among selected cowpea varieties. *M. Sc. (Agri.) Thesis*, School of Agril. and Env't. Sci., Univ. of Limpopo, South Africa.
- Rima Taipodia and Nabam, A. T., 2013, Impact of time of sowing spacing and seed rate on potential seed production and fodder quality of cowpea (*Vigna unguiculata* L. Walp). *J. Agril. Veter. Sci.*, 4(4): 61-68.
- Sadeghipour, O., 2008, Response of mungbean varieties to different sowing dates. *Pak. J. Biol. Sci.*, 11(16): 2048-2050.
- Sah, M. K., Sah, S. K., Ranjan, R., Nancee and Sah, J. N., 2013, Growth and productivity of cowpea (*Vigna unguiculata* L. Walp) varieties at different seeding dates and soil fertility management in chitwan, Nepal. *Proc. Nation. Symp. Abiotic and Biotic Stress Management in Veg. Crops*, Indian Society of Veg. Sci., New Delhi.
- Sestak, A. L., Catasky, T. and Jarvis, P. G., 1971, *Plant Photosynthetic Production Manual of Methods*, Ed. Dr. Junk, W. N. V., Publication, The Hague, pp. 343-345.
- Sharma, J., 1991, Performance of cowpea cultivar under different dates of planting and row spacing. *Madras Agril. J.*, 78(9-12): 372-374.
- Shiringani, R. P. and Shimelis, H. A., 2011, Yield response and stability among cowpea genotypes at three planting dates and test environments. *African J. Agril. Res.*, 6(14): 3259-3263.
- Shivakumar, Mishra, S. N. and Kumar, S., 2002, Effect of intergenotypic competition on yield assessment at different spacings in cowpea (*Vigna unguiculata* L. Walp). *Indian J. Genet. Plant Breed.*, 62(1): 38-41.
- Shivananda Malagi, C., 2005, Response of cowpea genotypes to plant density and fertilizer levels under rainfed vertisols. *M. Sc. (Agri.) Thesis*, Univ. Agril. Sci., Dharwad, India.
- Singh, G., Sekhon, H. S., Sandhu, J. S., Singh, S. J., Gumber, R. K., Randhwa, A. S., 2003, Effect of location and seed rate on three genotypes of mungbean. *Tropical Sci.*, 43:116-120.
- Soomro, N. A. and Khan, H. R., 2003, Response of mungbean genotypes to different dates of sowing in *kharif* season under rainfed conditions. *Asian J. Plant Sci.*, 2(4): 377-379.
- Subbiah, S. and Asija, J., 1956, A rapid producer for the estimation of available nitrogen in soil. *Current Sci.*, 25: 259-260.
- Tandan, H. L. S., 1998, Methods of analysis of soils, plant, water and fertilizers. *Fertilizer development and consultation organization*, 31: 9-16.
- Thakur Singh and Dhingra, K. K., 1993, Response of mungbean (*Vigna radiata* L.) cultivars to time of sowing under south western region of Punjab. *J. Res. Punjab Agric. Univ.*, 30(3-4): 157-159.
- Ugur Basaran, Ilknur Ayan, Zeki Acar, Hanife Mut and Ozlem Onal, A., 2011, Seed yield and agronomic parameters of cowpea (*Vigna unguiculata* L.) genotypes grown in the black sea region of Turkey. *African J. Biotech.*, 10(62): 13461-13464.
- Vishwanath, P. L. and Nadarajan, N., 1996, Genotype and environment interaction for grain yield in cowpea. *Madras Agril. J.*, 83(11): 707-708.
- Vishwanath, P. L., Murugesan, S., Ramamurthy, N. and Veerabadrán, P., 1997, Vamban-1, a new cowpea variety for Tamil Nadu. *Madras Agril. J.*, 84(5): 271-272.
- Vivekanandan, A. S., Gounasena, H. P. M. and Sivanaygan, T., 1972, Statistical evaluation of leaf area of plants. *Indian J. Agril. Sci.*, 42: 857-860.
- Yadav, G. L., 2003, Effect of sowing time, row spacing and seed rate on yield of cowpea under rainfed condition. *Indian J. Pulse Res.*, 16(2): 157-15.

Appendix I: Weekly rainfall data of MARS, Dharwad, during crop growth period (2013)

Std. week	Date	Rainfall (mm)	Rainy days
26	25 th June-1 st July	24.8	4
27	2 nd July-8 th July	16.2	2
28	9 th July-15 th July	27.8	4
29	16 th July- 22 nd July	36.8	3
30	23 rd July- 29 th July	85.6	6
31	30 th July- 5 th August	59.6	6
32	6 th August- 12 th August	18.4	1
33	13 th August- 19 th August	12.0	1
34	20 th August- 26 th August	11.6	3
35	27 th August- 2 nd September	8.0	-
36	3 rd September- 9 th September	9.4	2
37	10 th September- 16 th September	97.0	6
38	17 th September- 23 rd September	15.4	3
39	24 th September- 30 th September	6.4	1
40	1 st October- 7 th October	10.2	1
41	8 th October- 14 th October	-	-
42	15 th October- 21 st October	17.6	1
43	22 nd October- 28 th October	47.6	4
44	29 th October- 4 th November	-	-
45	5 th November- 11 th November	-	-

Appendix II: Prices of input and output

Particulars	Price (₹)
1. Inputs	
a) Seed cowpea	60.00 kg ⁻¹
b) Deep tillage	3000.00 ha ⁻¹
c) Harrowing	600.00 ha ⁻¹
d) Sowing and fertilizer application	1256.00 ha ⁻¹
e) Intercultivation (bullock pair)	600.00 ha ⁻¹
f) Weeding	942.00 ha ⁻¹
g) Harvesting and threshing	2198.00 ha ⁻¹
2. Fertilizers	
a) Urea	6.00 kg ⁻¹
b) DAP	26.00 kg ⁻¹
c) MOP	18.00 kg ⁻¹
3. Labour wages	
a) Men labour	157.00 day ⁻¹
b) Women labour	157.00 day ⁻¹
4. Plant protection chemicals	
a) Alachlor	450.00 litre ⁻¹
b) Confidor	2700.00 litre ⁻¹
c) Hexaconazole	530.00 litre ⁻¹
d) Ranaxypr	1566.00 100 ml ⁻¹
5. Outputs	
b) Grain	4000.00 quintal ⁻¹
c) Haulm	800.00 tonne ⁻¹

Appendix III: Treatment wise details of cost of cultivation of cowpea

Sl.No.	Combinations	land ploughing (Tractor)	Bullock Harrowing	Cost of seeds	Sowing (Dibbling)	Cost of fertilizer	Application charges	Inter cultivation	Hand weeding	Chemical Cost	Application charges	Harvesting Pod picking	Threshing	COC
1	D1S1G1	3000	600	1800	942	3624	314	600	942	1080	314	1570	628	15414
2	D1S1G2	3000	600	1800	942	3624	314	600	942	1080	314	1570	628	15414
3	D1S2G1	3000	600	1800	942	3624	314	600	942	1080	314	1570	628	15414
4	D1S2G2	3000	600	1800	942	3624	314	600	942	1080	314	1570	628	15414
5	D1S3G1	3000	600	1800	942	3624	314	600	942	1080	314	1570	628	15414
6	D1S3G2	3000	600	1800	942	3624	314	600	942	1080	314	1570	628	15414
7	D2S1G1	3000	600	1800	942	3624	314	600	942	2128	471	1570	628	16619
8	D2S1G2	3000	600	1800	942	3624	314	600	942	2128	471	1570	628	16619
9	D2S2G1	3000	600	1800	942	3624	314	600	942	2128	471	1570	628	16619
10	D2S2G2	3000	600	1800	942	3624	314	600	942	2128	471	1570	628	16619
11	D2S3G1	3000	600	1800	942	3624	314	600	942	2128	471	1570	628	16619
12	D2S3G2	3000	600	1800	942	3624	314	600	942	2128	471	1570	628	16619
13	D3S1G1	3000	600	1800	942	3624	314	600	942	1345	314	1570	628	15679
14	D3S1G2	3000	600	1800	942	3624	314	600	942	1345	314	1570	628	15679
15	D3S2G1	3000	600	1800	942	3624	314	600	942	1345	314	1570	628	15679
16	D3S2G2	3000	600	1800	942	3624	314	600	942	1345	314	1570	628	15679
17	D3S3G1	3000	600	1800	942	3624	314	600	942	1345	314	1570	628	15679
18	D3S3G2	3000	600	1800	942	3624	314	600	942	1345	314	1570	628	15679

COC- Cost of cultivation

Appendix IV: Percent disease index (PDI) of rust and Percent pod damage by pod borer on cowpea genotypes as influenced by sowing windows and planting geometry.

Treatment		PDI of rust				Percent pod damage			
Date of sowing (D)	Genotypes (G)	S1	S2	S3	Mean	S ₁	S ₂	S ₃	Mean
D ₁ : II FN of June	G ₁	7.30(15.6)	7.85(16.3)	7.12(15.5)	7.42(15.8)	14.34(22.2)	15.94(23.4)	14.94(22.8)	15.07(22.8)
	G ₂	9.63(18.1)	9.43(17.9)	8.15(16.6)	9.07(17.5)	14.81(22.6)	12.32(20.5)	25.93(29.9)	17.69(24.4)
	Mean	8.46(16.8)	8.64(17.1)	7.63(16.0)	8.25(16.7)	14.57(22.3)	14.13(21.9)	20.44(26.3)	16.38(23.6)
D ₂ : I FN of July	G ₁	11.93(20.0)	9.54(17.73)	9.67(18.1)	10.38(18.6)	43.48(41.2)	27.46(31.6)	31.88(34.4)	34.27(35.7)
	G ₂	13.82(21.7)	14.01(21.9)	12.18(20.1)	13.34(21.3)	29.64(33.0)	31.55(34.2)	34.21(35.9)	31.8(34.3)
	Mean	12.87(20.9)	11.78(19.9)	10.93(19.3)	11.86(20.0)	36.56(37.1)	29.51(32.9)	33.05(35.1)	33.04(35.0)
D ₃ : II FN of July	G ₁	15.42(23.1)	14.07(21.9)	11.22(19.5)	13.57(21.5)	21.52(27.6)	22.48(28.3)	24.80(29.4)	22.93(28.5)
	G ₂	19.03(25.9)	18.11(25.2)	17.85(24.9)	18.33(25.3)	29.53(32.9)	23.89(29.2)	25.92(30.1)	26.45(30.7)
	Mean	17.22(24.5)	16.09(23.5)	14.54(22.2)	15.95(23.4)	25.53(30.3)	23.19(28.7)	25.36(29.8)	24.69(29.6)
Mean of G ₁		11.55(19.6)	10.49(18.6)	9.34(17.7)	10.46(18.6)	35.88(35.9)	33.40(34.5)	34.69(35.3)	34.66(35.3)
Mean of G ₂		14.16(21.9)	13.85(21.7)	12.73(20.7)	13.58(21.4)	34.54(35.3)	34.76(35.2)	42.05(40.4)	37.12(36.9)
Mean		12.85(20.7)	12.17(20.2)	11.03(19.2)		35.21(35.6)	34.08(34.8)	38.37(37.7)	
Sources		S. Em ±		CD (P = 0.05)		S. Em ±		CD (P = 0.05)	
Date of sowing (D)		0.51		1.99		2.06		8.08	
Row Spacing (S)		0.35		NS		0.98		NS	
Genotype (G)		0.36		1.06		0.68		NS	
D X S		0.60		NS		1.69		NS	
D X G		0.62		NS		1.18		NS	
S X G		0.62		NS		1.18		NS	
D X S X G		1.07		NS		2.04		NS	

Figures in parentheses indicate arc-sign transformation values

Appendix V: List of Abbreviations

%	Per cent
°C	Degree Celsius
B:C	Benefit cost ratio
CD	Critical difference
COC	Cost of cultivation
cm	Centimetre
Cm ² plant ⁻¹	Centimetre square per plant
dm ²	Decimetre square
dm ² plant ⁻¹	Decimetre square per plant
DAS	Days after sowing
EC	Exchangeable cat ions
pH	Negative logarithm of hydrogen ion
<i>et al.</i>	and co workers
g	Grams
g plant ⁻¹	gram per plant
g m ⁻²	Gram per meter square
ha ⁻¹	Per hectare
HI	Harvest index
<i>i.e.,</i>	That is
kg	Kilograms
kg ha ⁻¹	Kilogram per hectare
kg NPK ha ⁻¹	Kilogram nitrogen, phosphorus, potassium per hectare
NPK	Nitrogen, phosphorus, potassium
kg N ha ⁻¹	Kilogram nitrogen per hectare
Kg P ₂ O ₅ ha ⁻¹	Kilogram phosphorus per hectare
Kg K ₂ O ha ⁻¹	Kilogram potassium per hectare
LA	Leaf area
LAI	Leaf area index
LAD	Leaf area duration
m	Meter
m ⁻²	Per square meter
m ²	Square meter
MARS	Main Agriculture Research Station
m t	Million tones
mg	Milligram
mg plant ⁻¹	Milligram per plant
ml	Millilitres
` ha ⁻¹	Rupees per hectare
S.Em	Standard error of mean
CD	Critical difference
I, II	First, Second

RESPONSE OF COWPEA (*Vigna Unguiculata* L.) GENOTYPES TO SOWING WINDOWS AND PLANTING GEOMETRY UNDER NORTHERN TRANSITIONAL ZONE OF KARNATAKA

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2014

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ABSTRACT

The experiment was carried out to study the effect of sowing dates and planting geometry on growth attributes, yield attributes, seed yield and economics of two cowpea genotypes. The field trial was conducted during *kharif* 2013 under rainfed conditions in split-split plot design with three replications at Main Agricultural Research Station, Dharwad. The experiment comprised of three dates of sowing (June second fortnight, July first fortnight and July second fortnight) in main plot, three row spacings (30, 45 and 60 cm) in sub plot and two genotypes (DC 15 and C -152) in sub-sub plot.

Results of the investigation indicated that significantly higher seed yield (1155 kg ha^{-1}), haulm yield (2535 kg ha^{-1}), net return ($\text{₹ } 32816 \text{ ha}^{-1}$) and B:C ratio (3.13) were recorded in cowpea sown during second fortnight of June as compared to first and second fortnight of July sowing. Similar trend was observed for growth and yield attributing parameters such as number of branches, leaf area, leaf area index, leaf area duration, total dry matter production, number of pods plant^{-1} , seed weight plant^{-1} . Among the row spacings significantly higher growth and yield attributes, seed yield (1062 kg ha^{-1}), haulm yield (2373 kg ha^{-1}), net return ($\text{₹ } 28751 \text{ ha}^{-1}$) and B:C ratio (2.83) were recorded in 45 cm row spacing and it was on par with 30 cm as compared to 60 cm row. Genotype DC 15 recorded significantly higher growth and yield attributing parameters, seed yield (1026 kg ha^{-1}), haulm yield (2279 kg ha^{-1}), net return ($\text{₹ } 27238 \text{ ha}^{-1}$) and B:C ratio (2.73) as compared to C-152.