EFFECT OF PLANT DENSITY ON GROWTH AND YIELD OF GROUNDNUT CULTIVARS UNDER RAINFED CONDITION

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CERTIFICATE

This is to certify that the thesis entitled "**EFFECT OF PLANT DENSITY ON GROWTH AND YIELD OF GROUNDNUT CULTIVARS UNDER RAINFED CONDITION**" submitted by **Mr. SREENIVAS C. METI**, for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRONOMY** to the University of Agricultural Sciences, Dharwad, is a record of research carried out by him during the period of his study in this University, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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Introduction

I. INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is regarded as the king of vegetable oilseeds on account of its diversified uses. Possibly no crop in the world has potentialities of being processed in as many ways and used in as many products as does groundnut (Woodroof, 1973). Groundnut kernels are mainly used for oil extraction in India. Its kernels are widely acknowledged as rich and cheap source of vegetable protein (26%). The protein content of an ounce of roasted groundnut is nearly as much as that of dhal, mutton, egg and milk (John, 1942). Kernels also contain vitamin A, B and some members of B_2 group. Minerals like phosphorus, calcium and iron are present in significant amount. Therefore, groundnut is almost a class by itself amongst low priced food products.

Groundnut is an important oilseed crop of tropical and subtropical region of the world. Cultivation of this crop is mostly confined to the geographical belt between 40°N and 45°S latitude. The area under this crop in the world is about 25.10 million hectares with production of 34.39 million tonnes and productivity of about 1370 kg ha^{-1} (Anonymous, 2001).

India is the largest groundnut growing country accounting 27.37 per cent of world area (6.87 million hectares) and 15.44 per cent of production (5.31 million tonnes) with productivity of 774 kg ha^{-1} (Anonymous, 2001). Groundnut occupies 29.86 per cent of total oilseeds area and contributes 35.22 per cent to total oilseed production in India.

In Karnataka, it is being cultivated over an area of 1.11 million hectares with a production of 0.79 million tonnes (16.16% of area and 14.88% of India's production) and productivity of 715 kg ha^{-1} (Anonymous, 2001), which is lower than the world and India's average productivity.

Investigations into the causes for low productivity in the state have been made by several study teams and have precisely indicated that farmers hardly use $2/5^{th}$ to $3/5^{th}$ of seed rate recommended for the crop, which has resulted in lower plant density per unit area and has finally led to poor yields. The other reasons for low yields are; use of local seed material, untimely sowing, poor crop management practices including non-application of organic manures/composts and incidence of pest and diseases.

Cultivars play an important role in groundnut production. Efforts made by All India Co-ordinated Research Project on Groundnut (AICRP), International Crops Research Institute for Semi-Arid Tropics (ICRISAT) and University of Agricultural Sciences, Dharwad have shown that, with the development of high yielding cultivars, it is possible to grow groundnut more profitably. A cultivar would express its full potential only when it is backed up by good agronomic practices. Optimum plant density provides conditions for maximum light interception right from early period of crop growth. Further, it is important to realize that plant density should be defined not only interms of number of plants per unit area (i.e. plant density) but also interms of arrangement of these plants on the ground (planting geometry/spatial arrangement). Further, increase in plant density beyond the optimum level decreases the yield of groundnut (Charner and Ashiri, 1974). Groundnut cultivars differ in their yielding ability. There is considerable inconsistency in response of cultivars to plant density. This calls for a need to generate more information on the response of groundnut cultivars to plant density for realizing their full potential in a given agro-climatic condition.

Recently, University of Agricultural Sciences, Dharwad has identified cv. GPBD 4 for *kharif* and cv. TAG 24 for post rainy/summer season. However, little information is available in Karnataka, in general, and in Northern Transitional Zone (Zone 8) of Karnataka in particular on the response of these two cultivars to varied plant density as against the national check cv. JL 24. Thus, investigation on the performance of groundnut cultivars to varied plant density was therefore, carried out during *kharif*, 2001 under rainfed conditions with the following objectives.

1. To study the performance of groundnut cultivars during *kharif*
2. To work out the optimum plant density requirement of groundnut cultivars.

Review of Literature

II. REVIEW OF LITERATURE

The literature pertaining to the effect of plant density on the growth and yield of groundnut cultivars is briefly reviewed and presented in this chapter.

2.1 Performance of groundnut cultivars

Among the main factors influencing the pod yield in groundnut, selection of suitable high yielding cultivar that produce more number of pods of uniform maturity and pod yield plays very important role.

2.1.1 Morphological character

Plant height was differed among different groundnut cultivars. In an evaluation of groundnut cultivars at Akola, Patil *et al.* (1995) reported that cv. JL 24 recorded more plant height (33 cm) as compared to cv. SB XI (31 cm) and TAG 24 (13 cm) during *kharif*, but during summer season taller plants were noticed in cv. SB XI (23 cm) as compared to cultivars ICGS 11 (17 cm), UF 70103 (15 cm) and TAG 24 (12 cm). Gawasane *et al.* (1988) noticed variation in plant height (40.85 to 50.30 cm) among different groundnut cultivars (TG 19a, Robost 33-1, JL 24 and POL 2). In AICRP multilocation trails (Anonymous, 2000), cv. JL 24 recorded more plant height (42.4 cm) as compared to cv. TAG 24 (27.1 cm) at harvest.

Difference in number of branches plant^{-1} among the groundnut cultivars was noticed by several workers. Range of variability was between 8.33 to 10.75 plant^{-1} among groundnut cultivars (Robost 33-1, POL 2, TG 19a and JL 24) (Gawasane *et al.*, 1988). Cultivar SB XI produced more number of branches plant^{-1} as compared to cv. TAG 24 and cv. JL 24 (Patil *et al.*, 1995). In AICRP multilocation trials, more number of branches plant^{-1} were observed in cv. JL 24 compared to cv. TAG 24 (Anonymous, 2000).

2.1.2 Growth parameters

Several workers reported a wide range of variability in total dry matter production plant^{-1} in the genetic resources of groundnut. Marani *et al.* (1961) noticed range of variability was between 649 to 878 g m^{-2} among the different groundnut cultivars (Spanish 33 and Virginia bunch, respectively). Biradar (1982) indicated that cv. Dh 3-30 produced more dry matter plant^{-1} (29.07 g) as compared to cv. TG 17 (22.90 g). Sanjeev kumar and Aravind kumar (1999) reported that cv. SG 84 and cv. Chitra showed difference in leaf and stem dry matter. The variation in leaf dry matter was between 2.76 to 14.93 g and that of stem dry matter was between 11.83 to 17.13 g, respectively. Gawasane *et al.* (1988) opined that leaf dry matter was more in cv. Robost 33-1, whereas cv. JL 24 produced more stem and total dry matter plant^{-1}. Kumari and Singh (1990) noticed linear increase in total dry matter production from 30-110 days in virginia group (K_2 and ICGS 4); and from 30-90 days in Spanish group (TG 17, JL 11 and JL 24) and valencia group (Gangapuri) on the contrary, Reddy and Gajendra Giri (1989) reported that cv. M 13 and cv. Kadiri 3 did not show difference in total dry matter plant.

Considerable variation in leaf area plant^{-1} among different groundnut cultivars was reported. Leaf area plant^{-1} ranged between 14.01 to 16.09 dm^2 among the groundnut cultivars (TG 1, Dh 3-30, TG 17 and TG 3) at 90 days after sowing (DAS) as noticed by Biradar (1982); and between 21.84 to 27.79 dm^2 among the different groundnut cultivars (TG 19a, POL 2, JL 24 and Robost 33-1) at 90 DAS as reported by Gawasane *et al.* (1988) .

Reddy and Gajendra Giri (1989) noticed groundnut cultivars (Kadiri 3 and M 13) showed difference in leaf area index and it was ranged between 2.67 to 3.21, respectively. Higher leaf area index (6.3) was noticed in cv. SG 84 as compared to cultivars TG 26, TG 25 and ICGS 11 (5.6, 5.9 and 6.1, respectively) (Kaul, 1999).

2.1.3 Yield and yield components

Several research workers noticed considerable variation in total number of pods plant^{-1} in different groundnut cultivars. Reddy and Gajendra Giri (1989) observed that cv. M 13 produced less number of pods plant^{-1} (17.2) as against 20.4 in cv. Kadiri 3. Sanjeev kumar and Aravind kumar (1999) noticed that, groundnut cultivars (ICGS 5 and TAG 24) induced difference in total number of pods plant^{-1} and they ranged between 20.6 and 34.3 plant^{-1}, respectively. In AICRP multilocation trials, cv. TAG 24 recorded more number of pods plant^{-1} (17.0) as compared to cv. JL 24 (15.4) (Anonymous, 2000). On the contrary, Raghavaiah *et al.* (1995) observed that change in total number of pods plant^{-1} was least due to the impact of groundnut cultivars (DRG 17 and Kadiri).

Dry pod weight plant^{-1} of groundnut differed significantly among the groundnut cultivars. Reddy and Gajendra Giri (1989) noticed that cv. Kadiri 3 weighed 19.5 g dry pod weight plant^{-1} as compared to 17.6 g plant^{-1} in cv. M 13. Sanjeev kumar and Aravind kumar (1999) reported that dry pod weight plant^{-1} was varied between cultivars (Dh 45 and TAG 24) to the tune of 17.46 to 27.13 g, respectively. In AICRP multilocation traits, cv. TAG 24 produced more dry pod weight plant^{-1} (13.45 g) as compared to cv. JL 24 (10.90 g) (Anonymous, 2000). On the contrary, Raghavaiah *et al.* (1995) did not notice variation in dry pod weight plant^{-1} between groundnut cultivars (DRG 17 and Kadiri).

Considerable variation in shelling percentage was noticed among different groundnut cultivars. Agasimani *et al.* (1984) reported that shelling percentage of groundnut cultivars (TG 1, M 13 and Dh 3-30) ranged between 72.8 to 79.0. Patil *et al.* (1995) opined that cv. JL 24 recorded high shelling percentage (69.4) as compared to cv. TAG 24 (60.0). Patil and Nagaraja (1999) noticed that cv. TAG 24 recorded lower shelling percentage (72.25) as compared to cv. JL 24 (73.80). Whereas, at Digraj, in AICRP multilocation trials cv. TAG 24 recorded higher shelling percentage (73.25) as compared to cv. JL 24 (72.25) (Anonymous, 1998). In contrast, Gawasane *et al.* (1988) did not observe variation in shelling percentage among groundnut cultivars (POL 2, TG 19a and Robost 33-1).

100-kernel weight (g) was high in cv. M 13 (59.8 g) as compared to cv. Kadiri (46.1 g) as reported by Reddy and Gajendra Giri (1989). Patil *et al.*(1995) reported that cv. TAG 24 recorded lower 100-kernel weight (21.6 g) as compared to cv. JL 24 (31.3 g). In AICRP trials, cv. JL 24 recorded higher 100-kernel weight compared to cv. TAG 24 (Anonymous, 2000).

Groundnut cultivars showed wide range of variability in percentage of sound mature kernels. Patil and Nagaraja (1999) reported that cv. TAG 24 resulted in higher percentage of sound mature kernels (86.12) as compared to cultivars TMV 2, Dh 3-30, Dh 40 and JL 24 (69.90, 70.19, 71.35 and 73.38, respectively). In AICRP multilocation trials cv. TAG 24 recorded higher percentage of sound mature kernels compared to cv. JL 24 (Anonymous, 1998 and 2000).

Dhopte and Ramteke (1994) noticed cv. TAG 24 recorded higher dry pod yield in vertisols. Whereas, cv. JL 24 recorded higher dry pod yield in shallow soils. Dry pod yield of cv. TAG 24 was 44.95 and 55.55 per cent higher than cv. JL 24 and SB XI, respectively (Patil *et al.*, 1995). Jayaramaiah and Timmegouda (1997) observed that cv. JL 24 performed better with respect to dry pod yield (3.98 t ha^{-1}) as compared to cv. TMV 2 (3.05 t ha^{-1}). In most of the AICRP multilocation trials, cv. TAG 24 recorded higher dry pod yield compared to cv. JL 24 (Anonymous, 1998 and Anonymous, 2000).

Sanjeev Kumar and Aravind kumar (1999) found that, cv. TAG 24 recorded higher kernel yield (1370 kg ha^{-1}) as compared to cv. SB XI (1240 kg ha^{-1}) and cv. Dh 45 (1166 kg ha^{-1}). In AICRP multilocation trials, cv. TAG 24 recorded higher kernel yield (1704 kg ha^{-1}) compared to cv. JL 24 (1335 kg ha^{-1}) (Anonymous, 2000).

Wide range of variation in dry haulm yield ha^{-1} was observed among different groundnut cultivars as reported by different workers. Reddy and Gajendra Giri (1989) noticed cv. M 13 recorded 5.2 per cent higher dry haulm yield as compared to cv. Kadiri 3. Whereas, 59.6 per cent higher in cv. LGN 2 over cv. TAG 24 as reported by Jadhav *et al.* (2000). In AICRP multilocation trials, dry haulm yield ha^{-1} was higher in cv. JL 24 compared to cv. TAG 24 (Anonymous, 2000). However, Jadhao *et al.* (1992); and Reddy and Reddy (1998) did not observe variation in dry haulm yield among the cultivars (SB XI and UF 70103; and TMV 2 and K 134, respectively).

Cultivar TAG 24 recorded higher harvest index (56.5) as compared to cv. DF 701013 (18.3) (Deshmukh *et al.*, 1993). Whereas, Patil *et al.* (1995) indicated that cv. JL 24 recorded lower harvest index (26.6) as compared to cv. TAG 24 (56.5).

2.1.4 Quality

Difference in oil content (%) among groundnut cultivars was noticed by several workers. Oil content (%) was higher in cv. TAG 24 (52.4) as compared to cv. JL 24 (51.0) (Patil *et al.*, 1995). On the contrary, Reddy and Gajendra Giri (1989) reported that oil content (%) of cv. M 13 and cv. Kadiri 3 did not differ significantly.

Sanjeev kumar and Aravind kumar (1999) reported that cv. TAG 24 produced high oil yield (640 kg ha^{-1}) as compared to cultivars Dh 45 (526 kg ha^{-1}), AK 12-24 (588 kg ha^{-1}) and ICGS 11 (629 kg ha^{-1}).

2.2 Effect of plant density

Spatial arrangement of a crop on the ground is widely recognized as one of the most important agro-technique. Groundnut requires an optimum space for the maximum realization of its inherent yield potential not because of its competition for actual space but because of its competition for nutrients, water, light, oxygen and carbon di-oxide. Groundnut varieties differ in their growth habit. Hence, the determination of optimal plant density is essential step in reducing competition and efficient utilization of available resource pool.

2.2.1 Morphological characters

Plant height of groundnut increased with increasing plant density (Mao and Hsu, 1975; Agasimani *et al.*, 1989; Mozingo and Steele, 1989; Mozingo *et al.*, 1990; and Deshmukh and Bhoi, 1999) on the contrary, taller plants were observed at 1,66,666 plants ha^{-1} as compared to 1,33,333 and 2,22,222 plants ha^{-1} (Choudhary *et al.*, 1997).

At low plant density, more number of branches $plant^{-1}$ were observed as compared to high plant density (Ishag, 1970; Kushwaha and Mishra, 1978; Mishra *et al.*, 1998). In contrast, increase in plant density increased the number of branches $plant^{-1}$ (Mao and Hsu, 1975).

The plant spread increased with decrease in plant density (Dehmukh and Bhoi, 1999). The plant spread increased from 20.7 to 22.8 cm due to decrease in plant density from 6.66 to 2.22 lakh plants ha^{-1}.

2.2.2 Growth parameters

Groundnut grown as low density crop, resulted in higher total dry matter $plant^{-1}$ (Chandrashekhara Reddy, 1976; Azu and Tanner, 1978; Biradar, 1982; Patil, 1984; Singh and Ahuja, 1985; Koppalkar, 1988; Kaul, 1999 and Nagaraj, 1999). Further, total dry matter $plant^{-1}$ was more at 25 plants m^{-2} as compared to 6.3, 11.1 and 100 plants m^{-2} (Tarimo and Blamey, 1999). In contrast, shoot dry matter $plant^{-1}$ was greater at higher plant density as compared to lower plant density (Lipscomb *et al*, 1964; and Goldin and Hartzook, 1986). On the other hand, Suraj Bhan and Mishra (1971); and Reddy and Gajendra Giri (1989) noticed that change in plant density did not affect the total dry matter plant.

Increase in plant density decreased the leaf area plant^{-1} (Chandrashekhara Reddy, 1976; Biradar, 1982; Patil, 1984 and Yargattikar, 1986). However, Koppalkar (1988) reported that leaf area plant^{-1} was unaffected due to change in plant density.

Lower plant density produced higher leaf area index (LAI) as reported by Chandrashekhara Reddy (1976). However, Nagaraj (1999) opined that increased plant density (74,074 to 1,48,148 plants ha^{-1}) increased the leaf area index (1.21 to 2.94, respectively).

2.2.3 Yield and yield components

Increase in total number of pods plant^{-1} due to increase in plant density (Ishag, 1970; Sarah, 1973; Laurence, 1974; Kushwaha and Mishra, 1978; Gopalaswamy *et al.*, 1979; Kvien and Bergmark, 1987; Reddy and Gajendra Giri, 1989; Jadhao *et al.*, 1992; Basak *et al.* 1995; Raghavaiah *et al.*, 1995; Ghosh *et al.*, 1997; Lukunchavan *et al.*, 1997a; Mishra *et al.*, 1998 and Patel, 1999). However, Dwivedi and Gautam (1992) indicated that for higher total number of pods plant^{-1}, medium plant density of 1,25,000 plant ha^{-1} was found optimum. On the other hand, total number of pods plant^{-1} were not affected by change in plant density (Nandania *et al.*, 1992).

The number of undeveloped pods plant^{-1} were 1.2 at 4,16,666 plants ha^{-1} compared to 3.4 at 2,22,222 plants ha^{-1} (Kushwaha and Mishra, 1978). On the contrary, decline in number of undeveloped pods plants^{-1} from 3.56 to 3.23 due to decrease in plant density from 1,48,148 to 74,074 plants ha^{-1} was observed by Nagaraj (1999). However, Patil (1984) observed that change in plant density did not affect the number of undeveloped pods plants^{-1}.

Reddy and Gajendra Giri (1989); Jadhao *et al.* (1992); and Nagaraj (1999) reported that increase in plant density decreased the dry pod weight plant^{-1}. In contrast, decrease in plant density decreased the dry pod weight plant^{-1} as reported by Mao and Hsu (1975); and Ghosh *et al.* (1997).

Shelling percentage of groundnut increased with decreasing plant density as opined by Kaul (1999). On the other hand, results of Nandania *et al.* (1992); Patel and Patel (1995); and Nagaraj (1999) revealed that shelling percentage of groundnut was not affected by change in the plant density.

At denser plant population, higher percentage of sound mature kernels was observed by Mozingo and Coffelt (1980). On the other hand, percentage of sound mature kernels was unaffected or affected meagrely due to change in plant density (Kvein and Bergmark, 1987 and; Mozingo and Steele, 1989).

At 1,48,148 plants ha^{-1}, 100 kernel weight of groundnut was 5.9 and 9.0 per cent higher than groundnut grown at 1,11,111 and 74,074 plants ha^{-1} as reported by Nagaraj (1999). However, many workers opined that change in plant density failed to excert significant influence on 100 kernel weight of groundnut (Reddy and Gajendra Giri, 1989; Raghavaiah *et al.*, 1995; Mishra *et al.*, 1998; and Patel, 1999).

Dry pod yield ha^{-1} increased with increase in plant density (Gopalaswamy *et al.*, 1979; Kvein and Bergmark, 1987; Biradar 1982; Donga *et al.*, 1990; Basak *et al.*, 1995); Patel and Patel, 1995; Lukunchavan *et al*, 1997a; and Nagaraj, 1999). On the other hand, Patel *et al.*, (1985) indicated that decrease in plant density from 3,33,333 to 2,22,222 plants ha^{-1} resulted in increase in dry pod yield from 3.39 to 3.64 t ha^{-1}. Whereas, Sandhu and Hundal (1993); Reddy and Reddy (1998); and Kaul (1999) reported that dry pod yield ha^{-1} was not influenced by change in plant density.

In a study on response of groundnut to plant density, Nagaraj (1999) reported that 1,48,148 plants ha^{-1} resulted in 10.2 and 17.6 per cent more kernel yield ha^{-1} than 1,11,111 and 74,074 plants ha^{-1}, respectively. Whereas, Singh and

Ahuja (1985) reported that higher kernel yield (13.0 q ha^{-1}) was obtained at optimum plant density (1,48,000 plants ha^{-1}). Further, he also observed that either decrease or increase in plant density beyond optimum resulted in reduction in kernel yield ha^{-1}.

Dry haulm yield was increased with increase in plant density (Jadhao *et al.*, 1992; Reddy and Reddy, 1998; Deshmukh and Bhoi, 1999 and Patel, 1999). On the other hand , dry haulm yield did not differ significantly due to change in plant density (Reddy and Gajendra Giri, 1989; and Kaul, 1999).

Groundnut grown at a plant density of 4,44,444 plants ha^{-1} produced lower harvest index (0.43) compared to a plant density of 2,66,666 plants ha^{-1} (0.46) as reported by Jadhav *et al.* (2000). Whereas, Nagaraj (1999) reported that harvest index did not vary due to change in plant density.

2.2.4 Quality

Kernel oil content (%) increased with decrease in plant density (Sathone and Babulkar, 1991; El-Seesy and Ashoub, 1994). Oil content of kernel did not differ significantly due to change in plant density. (Chandrashekhara Reddy, 1976; Reddy and Gajendra Giri, 1989; Nandania *et al.*, 1992; and Raghavaiah *et al.*, 1995). Salem *et al.* (1984) and Nagaraj (1999) observed that the oil yield (kg ha^{-1}) increased with increase in plant density.

2.3 Performance of groundnut cultivars at different plant density

2.3.1 Morphological characters

Cultivars showed differential response to change in plant density. Taller plants of cv. TG 3 and cv. TG 17 were noticed at a plant density of 3,33,333 and 1,66,666 plants ha^{-1}, respectively (Biradar, 1982).

2.3.2 Growth parameters

Biradar (1982) reported that cultivars TG 17, TG 1 and Dh 3-30 maximized their dry matter production $plant^{-1}$ at plant density of 1,66,666, 2,22,222 and 3,33,333 plants ha^{-1}, respectively.

Cultivar TG 17 produced more leaf area plant^{-1} (21.15 dm^2) at 2,50,000 plants ha^{-1} compared to other densities. However cv. TG 1 and cv. TG 3 produced high leaf area plant^{-1} (19.55 and 20.61 dm^2, respectively) at 2,22,222 and 1,66,666 plants ha^{-1}, respectively (Biradar, 1982).

2.3.3 Yield and yield components

Agasimani *et al.* (1984) reported that cultivars TG 1 and Dh 3-30 grown at 2,50,000 plants ha^{-1} produced more number of double seeded pods plant^{-1} (21.90 and 35.75, respectively). However, cv. M 13 produced more number of pods plant^{-1} (27.20) at 1,48,148 plants ha^{-1}.

Biradar (1982) noticed varietal differences with respect to pod weight plant^{-1} due to change in plant density. Dry pod weight plant^{-1} of cv. TG 1 cv. Dh 3 –30 was higher (12.77 and 15.47 g, respectively) at 2,22,222 plants ha^{-1}. However, cv. TG 17 and TG 1 recorded more dry pod weight plant^{-1} (12.99 and 15.12 g, respectively) at a plant density of 1,66,666 plants ha^{-1}.

Raghvaiah *et al.* (1995) observed differential response of groundnut cultivars to plant density. Cultivars DRG 17 and Kadiri 3 produced higher dry pod yield (4715 and 3461 kg ha^{-1}, respectively) at a plant density of 3,33,333 and 2,22,222 plants ha^{-1}, respectively. However, Mishra *et al.* (1998) noticed that high yields of cv. J 11 and cv. JL 24 (1553 and 1570 kg ha^{-1}, respectively) at a plant density of 2,22,222 plants ha^{-1}.

2.4 Correlation studies

Sanjeev kumar and Aravind Kumar (1999) observed that total number of branches plant^{-1} (r = 0.583*) and dry pod weight plant^{-1} (r = 0.901**) had significant and positive correlation with dry pod yield ha^{-1}.

Material and Methods

III. MATERIAL AND METHODS

Details of the materials used and the techniques adopted during the course of investigation "Effect of plant density on growth and yield of groundnut cultivars under rainfed condition" are described in this chapter.

3.1 Location

The field experiment was conduced at Main Research Station, University of Agricultural Sciences, Dharwad (Karnataka) to study the "**Effect of plant density on growth and yield of groundnut cultivars under rainfed condition**". The Main Research Station, Dharwad is located in Northern Transitional Zone (Zone 8) of Karnataka and is situated at 15° 26′ N latitude, 75° 07′ E longitude and an altitude of 678 m above mean sea level (MSL). The experiment was laid out in plot No. E.133 of Main Research Station, University of Agricultural Sciences, Yettinagudda Campus, Krishingar, Dharwad

3.2 Soils

The soil of the experimental site was medium black clayey in nature. Before the initiation of experiment, composite soil sample from 0 to 30 cm depth was collected. Soil sample was air dried, powdered and allowed to pass through 2 mm sieve. The soil sample was analysed for physical and chemical properties (c.f. Table 1). Analysis indicated that pH of the soil was 7.9 with medium in organic carbon (0.72%), medium in available nitrogen (308 kg N ha^{-1}), medium in available phosphorus (45.80 kg P_2O_5 ha^{-1}) and high in available potassium (408 kg K_2O ha^{-1}).

3.3 Climatic conditions

The data on climatic parameters such as rainfall (mm), mean maximum and mean minimum temperature (°C) and relative humidity (%) recorded at the Meteorological Observatory, Main Research Station, University of Agricultural

Table 1 : Physical and chemical properties of the soil of the experimental field

Particulars	Values	Method employed	Reference
I. Physical Properties			
Coarse sand (%)	06.00	International Pipette method	Piper (1966)
Fine sand (%)	13.86	International Pipette method	Piper (1966)
Silt (%)	26.67	International Pipette method	Piper (1966)
Clay (%)	53.47	International Pipette method	Piper (1966)
II. Chemical Properties			
pH (1:2.5 soil water suspension)	7.9	Potentiometric method	Piper (1966)
Electrical conductivity (dS m^{-1})	0.26	Conductivity bridge method	Jackson (1967)
Organic carbon (%)	0.72	Wet oxidation method	Jackson (1967)
Available nitrogen (kg N ha^{-1})	308	Alkaline permanganate method	Subbiah and Asija (1956)
Available phosphorus (kg P_2O_5 ha^{-1})	45.80	Olsen's method	Muhr et al. (1965)
Available potassium (kg K_2O ha^{-1})	408	Flame photometer method	Muhr et al. (1965)

Sciences, Dharwad, during the experimental year (2001) and the mean of 51 years (1950-2000) are presented in Table 2 and depicted in Fig.1.

The mean annual rainfall for the past 51 years at Main Research Station, Dharwad was 784.70 mm. Maximum rainfall (153.11 mm) received in the month of July followed by October (135.39 mm). The highest mean monthly maximum temperature (37.1°C) and the lowest mean monthly minimum temperature (13.41°C) were observed during the month of April and December, respectively. Mean monthly maximum relative humidity (87.88%) and mean monthly minimum relative humidity (51.25%) observed during the months of July and February, respectively.

The total rainfall received during the experimental year (2001) was 269.6 mm which was 65.64 per cent lower than the average of 51 years (784.73 mm). Likewise the crop received low rainfall (152.8 mm) in 17 rainy days during entire growth period (7^{th} July to 11^{th} October, 2001). The crop undergone severe moisture stress from 20^{th} August to 16^{th} September (c.f. Table 3). During the growth period the maximum rainfall (34.8 mm) was recorded during 31^{st} standard week (30^{th} July to 5^{th} August).

The mean maximum temperature of 31.1°C and mean minimum temperature of 19.9°C were recorded during 37^{th} standard week (10^{th} September to 16^{th} September), respectively. The highest relative humidity of 93.00 per cent was recorded in 27^{th} standard week (02 July to 08 July). The detailed weekly weather parameters during crop growth period (7^{th} July to 11^{th} October, 2001) are presented in Table 3.

3.4 Previous crops grown on the experimental area and land preparation

During the *rabi* season of 2000, the land was fallow. The land was ploughed with double mould board plough during the month of January. After the receipt of sufficient rainfall in the month of May and June (23.10 and 32.50 mm, respectively) the land was bought to fine tilth by repeated harrowing.

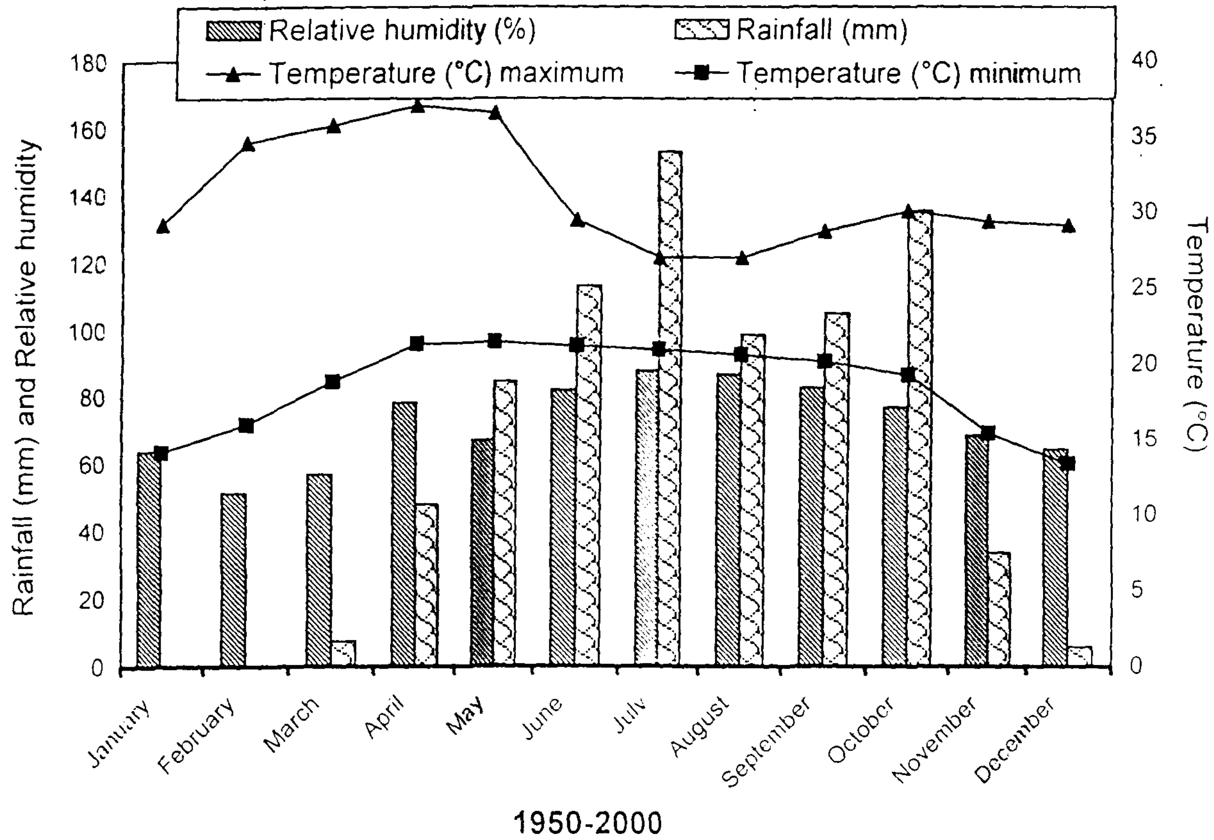
Table 2 : Monthly meteorological data for the experimental year (2001) and the mean of past 51 years (1950-2001) recorded at the meteorological observatory, Main Research Station, University of Agricultural Sciences, Dharwad (Karnataka)

Months	Rainfall (mm)		Temperature (°C)				Relative humidity (%)	
			Mean maximum		Mean minimum			
	2001	Mean*	2001	Mean*	2001	Mean*	2001	Mean*
January	0.00	0.10	29.90	29.21	16.00	14.11	55.00	63.90
February	0.00	0.00	34.00	34.61	16.80	15.95	50.00	51.25
March	0.00	7.37	35.30	35.76	18.50	18.78	45.00	56.92
April	52.10	47.90	35.70	37.10	22.00	21.32	55.00	78.28
May	23.10	84.61	34.80	35.59	21.50	21.45	59.00	67.16
June	32.50	113.10	30.30	29.48	21.30	21.20	75.00	82.00
July	**33.10**	**153.11**	**26.80**	**27.04**	**21.10**	**20.95**	**81.00**	**87.88**
August	**58.10**	**98.67**	**27.20**	**27.02**	**20.90**	**20.63**	**81.00**	**86.83**
September	**53.60**	**104.97**	**30.10**	**28.74**	**20.20**	**20.17**	**72.00**	**82.86**
October	**17.00**	**135.39**	**30.10**	**30.10**	**19.90**	**19.27**	**65.00**	**77.04**
November	0.00	33.75	31.00	29.39	17.90	15.41	55.00	68.68
December	0.00	5.76	29.60	29.15	13.70	13.41	55.00	64.58
	269.60	**784.70**						

* Mean of 51 years (1950-2001)

Table 3 : Weekly distribution of rainfall (mm) along with number of rainy days, mean maximum, mean minimum temperature (°C) and relative humidity (%) during crop growth period (7-7-2001 to 11-10-2001) as recorded at the meteorological observatory, Main Research Station, University of Agricultural Sciences, Dharwad (Karnataka)

Sl. No.	Standard week	Period	Rainfall (mm)	Number of rainy days	Temperature (°C)		Relative humidity (%)
					Mean max.	Mean min.	
1.	27	02 July to 08 July, 2001	10.9	2	30.4	21.2	85.90
2.	28	09 July to 15 July, 2001	13.0	2	25.8	20.9	85.30
3.	29	16 July to 22 July, 2001	2.0	0	27.1	20.9	80.95
4.	30	23 July to 29 July, 2001	7.2	1	27.1	21.4	81.75
5.	31	30 July to 05 August, 2001	34.8	2	27.6	21.0	79.60
6.	32	06 August to 12 August, 2001	0.6	0	27.4	21.3	79.60
7.	33	13 August to 19 August, 2001	14.0	3	26.2	20.9	84.80
8.	34	20 August to 26 August, 2001	4.3	0	26.2	20.6	81.95
9.	35	27 August to 02 September, 2001	4.4	0	28.7	20.4	74.75
10.	36	03 September to 09 September, 2001	0.0	0	29.9	25.6	72.35
11.	37	10 September to 16 September, 2001	0.0	0	31.1	19.9	68.60
12.	38	17 September to 30 September, 2001	33.3	3	30.2	20.8	72.40
13.	39	24 September to 30 September, 2001	20.3	2	29.7	29.7	74.15
14.	40	01 October to 07 October, 2001	4.5	1	29.3	29.3	76.15
15.	41	08 October to 14 October, 2001	3.5	1	29.1	29.1	76.60
		Total	**152.8**	**17**			



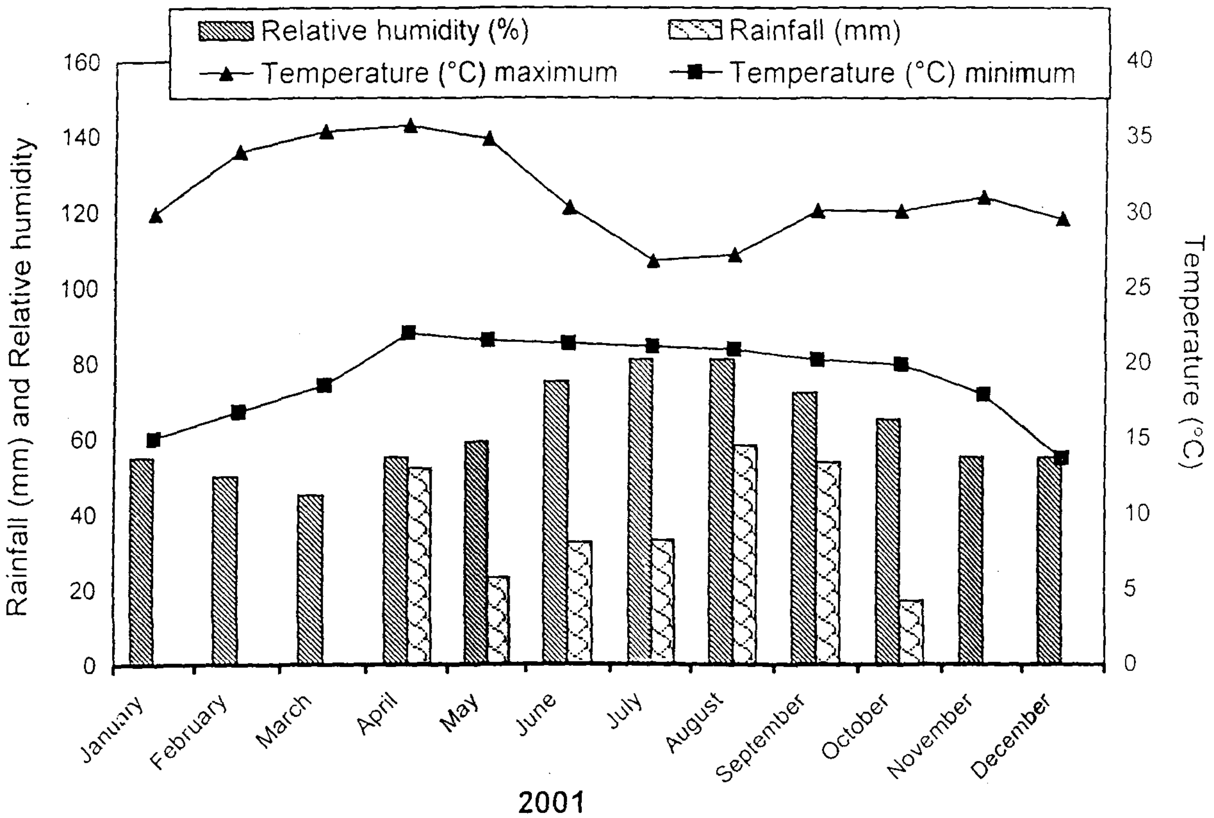


Fig. 1. Monthly meteorological data for the experimental year 2001 and mean of past 51 years (1950-2000) as recorded at the Meteorological Observatory, Main Research Station, University of Agricultural Sciences, Dharwad

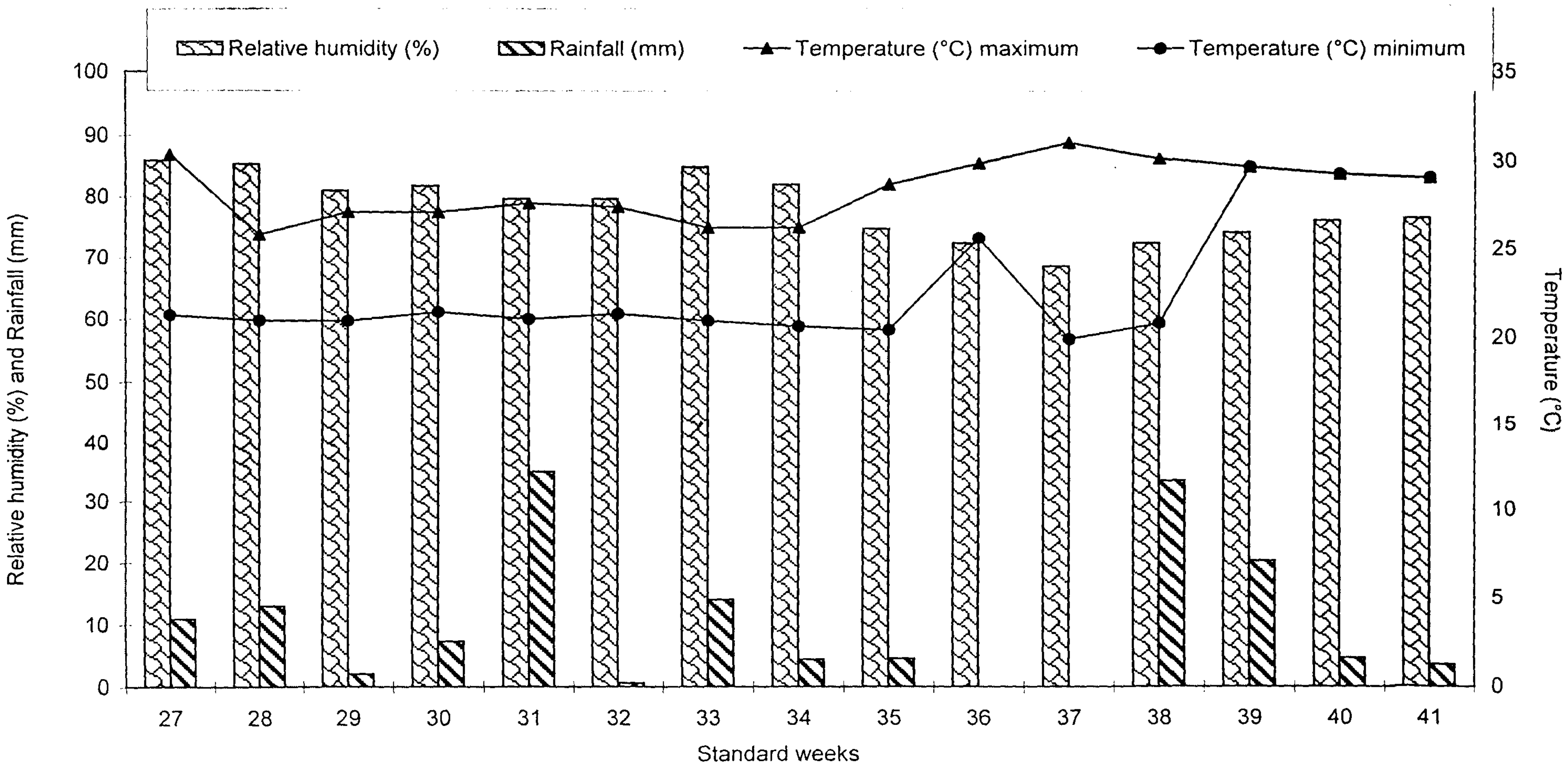


Fig. 2. Weekly distribution of rainfall (mm), mean maximum, mean minimum temeperature (°C) and relative humidity (%) during crop growth period (7-7-2001 to 11-10-2001) as recorded at the Meteorological Observatory, Main Research Station, University of Agricultural Sciences, Dharwad

3.5 Experimental details

A field experiment on groundnut was conducted during *kharif*, 2001 under rainfed conditions. The details of the experiment are presented in Table 4.

3.6 Salient features of groundnut cultivars used in the present investigation

The groundnut cultivars used in the present investigation were GPBD 4 (Gowda *et al.*, 2002) , TAG 24 and JL 24 (Patil *et al.*, 1995). The salient features of these cultivars are furnished in Table 5.

3.7 Application of fertilizers

Nitrogen (N) and phosphorus (P); and potassium (K) were applied in the form of diammonium phosphate (18%N and 46% P_2O_5) and muriate of potash (60% K_2O) respectively. Entire quantity of recommended dose of fertilizers (25 kg N, 75 kg P_2O_5 and 25 kg K_2O ha^{-1}) was applied at the time of sowing in small furrows opened at 30 or 45 cm spacing with a marker and mixed thoroughly with the soil.

3.8 Seed treatment and sowing

Prior to sowing, the seeds were treated with captan @ 3 g kg^{-1} seeds as a precautionary measure against collar rot and tikka diseases. Later, seeds were treated with rhizobium NC-92 strain which was collected from the Department of Agricultural Microbiology, University of Agricultural Sciences, Dharwad @ 2.5 g kg^{-1} seeds. For hand dibbling of seeds, the rows were opened 5 cm away from the fertilizer row by providing 30 cm or 45 cm spacing between two rows. Then seeds were hand dibbled in seed rows with a intra row spacing of either 10 or 15 or 20 cm depending upon the sub plot treatment (c.f. Table 4).

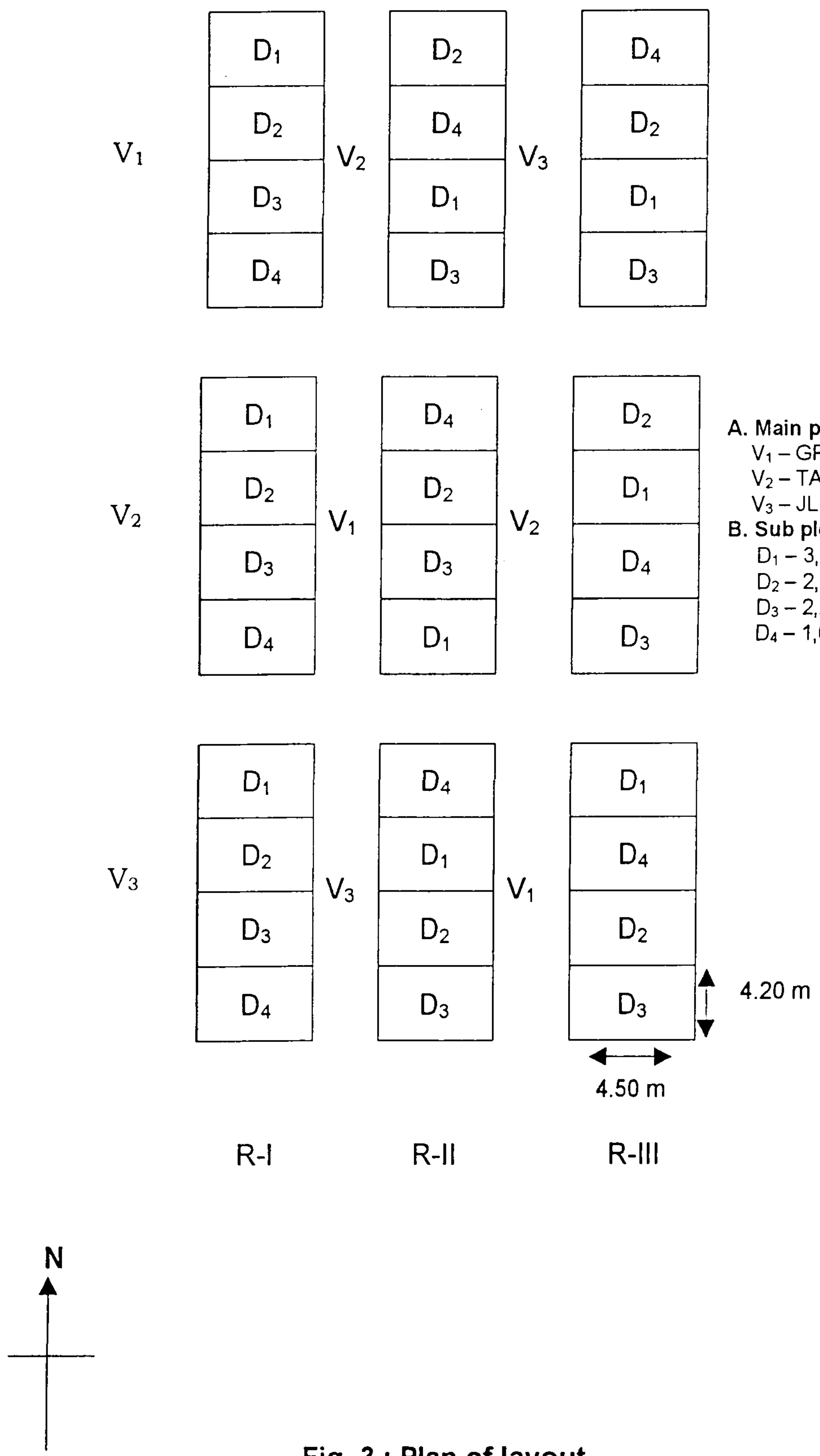
3.9 After care

Gap filling was taken upto 10 days after sowing (DAS) to maintain the required plant density. Experimental plots were kept weed free by integrated

Table 4 : Details of the experiment

Sl.No.	Particulars	Experiment
1.	**Title**	Effect of plant density on growth and yield of groundnut cultivars under rainfed condition
2.	**Cultivars**	GPBD 4, TAG 24 and JL 24
3.	**Design**	Split Plot Design
4.	**Treatments**	A. **Main plots (groundnut cultivars)** 1. GPBD 4 2. TAG 24 3. JL 24 B. **Sub plots (plant density)** 1. 3,33,333 plants ha^{-1} (30 cm × 10 cm) 2. 2,22,222 plants ha^{-1} (30 cm × 15 cm) 3. 2,22,222 plants ha^{-1} (45 cm × 10 cm) 4. 1,66,666 plants ha^{-1} (30 cm × 20 cm)
5.	**Replications**	3
6.	**Plot size (sub-plot)**	
	a. Gross plot	4.50 m × 4.20 m (18.90 m^2)
	b. Net plot	3.60 m × 3.60 m (12.96 m^2)
7.	**Layout**	c.f. Fig. 3.
8.	**Spacing**	Varied as per the sub-plot treatments (Plant density)
9.	**Date of sowing**	07-07-2001
10.	**Date of harvest**	
	GPBD 4	11-10-2001 (96)*
	TAG 24	09-10-2001 (94)*
	JL 24	11-10-2001 (96)*

* Figures in parenthesis indicate the number of days to harvest.



LEGEND

A. Main plots (groundnut cultivars)

V_1 – GPBD 4
V_2 – TAG 24
V_3 – JL 24

B. Sub plots (plant density ha^{-1})

D_1 – 3,33,333 (30 cm × 10 cm)
D_2 – 2,22,222 (30 cm x 15 cm)
D_3 – 2,22,222 (45 cm x 10 cm)
D_4 – 1,66,666 (30 cm x 20 cm)

Fig. 3 : Plan of layout

Table 5 : Salient features of groundnut cultivars used in the present investigation

Sl. No.	Characters/parameters	GPBD 4	TAG 24	JL 24
1.	Pedigree	KRG 1 X ICGV 86855	TGS 2 X TGE 1	Pure line selection from E.C. 94943
2.	Resistance	Late leaf spot and rust	Bud necrosis	-
3.	Growth habit	Bunch	Bunch	Bunch
4.	Maturity (days)	105-110	95-100	105-110
5.	Kernel oil content (%)	48	50.87	46-48
6.	100 kernel weight (g)	38.2	50-52	52-54
7.	Shelling percentage (%)	77	70	70
8.	Reference	Gowda *et al.* (2002)	Patil *et al.* (1995)	Patil *et al.* (1995)

Plate 1 : General view of the experimental field

weed management practices involving pre-emergence application of pendimethalin (30% EC) @ 1 kg a.i., ha^{-1} with two hand weedings at 30 and 45 days after sowing (DAS) and one intercultivation at 35 days after sowing (DAS). Since the crop undergone severe moisture stress during its growth period (34th to 37th standard week), one protective irrigation was given uniformly to a depth of 5 cm.

To control defoliaters (*Spodoptera* and *helicoverpa*) and sucking pests (Thrips), monocrotophos (36 SL) @ 1.5 ml l^{-1} and Lambda-cyhalothrin (0.05 EC) @ 1 ml l^{-1} was sprayed at seventh and thirteenth weeks after sowing, respectively. The crop was sprayed with carbendazim (50%WP) @ 0.5 g l^{-1} and mancozeb (75% WP) @ 2 g l^{-1} at seventh and thirteen weeks after sowing to control late leaf spot (*Cercospora arachidicola*) and leaf rust (*Puccinia archidis*), respectively.

3.10 Harvesting

The crop was harvested as and when the groundnut cultivars reached maturity (c.f. Table 4). Entire plants were uprooted from the net plot area of each treatment separately and spread in field for drying. Then pods were plucked from the plants. All dirt, soil impurities and immature pods were removed and developed pods were completely sun dried for a period of one week. Then pods were bagged to record pod weight.

3.11 Collection of experimental data and plant sampling procedure

For recording various biometric observation on groundnut, a sample consisting of five plants were selected at random form each net plot. For each sample, observations on various growth, yield and quality parameters were made at different stages of crop growth (30, 60, 90 DAS and at harvest). The procedure followed to record observations on each parameter are presented in Table 6.

Table 6 : Methods of recording observations on different parameters

Sl.No.	Parameter	Procedure followed
I.	**Morphological characters**	
1.	Plant height (cm)	Height from base of the plant to the tip of main stem
2.	Number of branches (plant^{-1})	Number of branches borne on the main stem of plant including small rudimentary ones
3.	Canopy spread (cm)	Maximum plant spread at the ground level perpendicular to the crop rows was measured with the help of scale
4.	Number of nodules plant^{-1} and nodule dry weight (g plant^{-1})	Number of nodules plant^{-1} was counted and nodules were oven dried at 65° to 70°C as nodule dry weight at 45 and 60 days after sowing (DAS)
II.	**Growth components**	
1.	Leaf area (dm^2 palnt^{-1}) (Vivekanandan *et al.*, 1972)	Disc method on dry weight basis $LA = \frac{Wa \times A}{Wb}$ Where, LA = Leaf area (dm^2 plant^{-1}) Wa = Weight of dry leaves + discs (g) A = Area of discs (cm^2) Wb = Weight of discs (g)
2.	Leaf area index (LAI) (Sestak *et al.*, 1971)	$LAI = \frac{\text{Leaf area palnt}^{-1}\ (dm^2)}{\text{Land area covered by individual plant}\ (dm^2)}$
3.	Dry matter production (g plant^{-1}) and its accumulation in different plant parts	Oven dry weight (drying at 70°C to a constant weight) of different plant parts after partitioning of whole plant into leaf, stem and reproductive parts* at different crop growth stages (30, 60 and 90 DAS and at harvest). The sum of mean dry weight of all plant parts represents total dry matter palnt^{-1} (g)

* Flower buds + flowers + gynophore and pods.

Table 6 Contd...

Sl.No.	Parameter	Procedure followed
III.	**Yield and yield parameters**	
1.	Number of pods ($plant^{-1}$)	Number of pods produced per plant were counted and recorded
2.	Number of developed and undeveloped pods ($plant^{-1}$)	Total number of developed and undeveloped pods produced per plant were counted and recorded
3.	Pod weight (g $plant^{-1}$)	Total pod weight obtained from whole plant
4.	Sound mature kernels (%)	Kernels sample obtained from shelled 200 g dry pods from each treatment were taken and well developed kernels were sorted and sound mature kernels (%) was worked out $\text{Sound mature kernels (\%)} = \frac{\text{Number of well developed kernels}}{\text{Total number of kernels}} \times 100$
5.	Hundred kernel weight (g)	Duplicate samples of 100 kernels from a sample of 200 g dry pods shelling from each treatment were choosen and weighed and average was noted
6.	Shelling percentage	From each net plot yield 200 g dry pods were weighed, shelled and shelling percentage was worked out $\text{Shelling (\%)} = \frac{\text{Weight of kernels (g)}}{\text{weight of dry pods (g)}} \times 100$
7.	Dry pod yield (kg ha^{-1})	Pods obtained from each net plot were sun dried and weighed and dry pod yield per hectare was worked out
8.	Kernel yield(kg ha^{-1})	$\text{Kernel yield (kg ha}^{-1}) = \frac{\text{Dry pod yield (kg ha}^{-1}) \times \text{shelling percentage}}{100}$

Table 6 contd...

Sl.No.	Parameter	Procedure followed
9.	Dry haulm yield (kg ha^{-1})	The dry haulm yield from each plot at harvest was recorded after separating the pods after complete sun drying for a period of one week; and dry haulm yield ha^{-1} was worked out
10.	Harvest index (HI) (Donald, 1962)	$HI = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})}$
IV.	**Quality parameters**	
1.	Oil content (%) (A.O.A.C., 1975)	Oil content of oven dried kernels was estimated by Nuclear Magnetic Resonance (NMR) method against a standard reference sample.
2.	Oil yield (kg ha^{-1})	$\text{Oil yield (kg ha}^{-1}) = \frac{\text{Oil percentage}}{100} \times \text{kernel yield (kg ha}^{-1})$
V.	**Economic analysis**	
1.	Benefit : cost ratio (B:C ratio)	To know the rate of return per rupee invested, B:C ratio was worked out by the following formula $\text{B:C ratio} = \frac{\text{Gross returns (Rs. ha}^{-1})}{\text{Cost of cultivation (Rs ha}^{-1})}$

3.12 Statistical analysis and interpretation of data

The data recorded on various characters were subjected to Fisher's method of analysis of variance and interpretation of data as given by Gomez and Gomez (1984). The level of significance used in 'F' and 't' tests was P = 0.05. Least Significant Difference (LSD) values were calculated whenever the 'F' test was significant. Correlation analysis were carried out to study the nature and degree of relationship between growth components and yield ; yield components and yield.

Experimental Results

IV. EXPERIMENTAL RESULTS

The results of the field experiment conducted to study the "Effect of plant density on growth and yield of groundnut cultivars under rainfed condition" are presented below.

For the sake of convenience in presenting the results in the text, sub plot treatment involving four plant densities of the experiment are classified as high plant density (3,33,333 plants ha^{-1}), medium plant density (2,22,222 plants ha^{-1}) and low plant density (1,66,666 plants ha^{-1}). Medium plant density of 2,22,222 plants ha^{-1} was achieved with two planting geometries such as 30 cm x 15 cm and 45 cm x 10 cm.

4.1 Morphological characters

4.1.1 Plant height (cm)

(c.f. Table 7)

Cultivars differed significantly with respect to plant height at all the growth stages except at 30 days after sowing (DAS). Plant height of cv. JL 24 was higher (23.27, 25.08 and 25.55 cm at 60, 90 DAS and at harvest, respectively) than cv. GPBD 4 and cv. TAG 24.

Effect of plant density (PD) was significant with respect to plant height at all the growth stages except at 30 DAS. Plants were taller in higher plant density (3,33,333 plants ha^{-1}) than in medium and lower plant densities (2,22,222 and 1,66,666 plants ha^{-1}, respectively).

Interaction effects of cultivars and plant density were not significant with respect to plant height at all the growth stages.

4.1.2 Number of branches $plant^{-1}$

(c.f. Table 8)

Cultivars did not differ significantly with respect to number of branches $plant^{-1}$ at all the growth stages.

Table 7 : Plant height (cm) of groundnut cultivars at different growth stages as influenced by plant density

Plant density (plants ha^{-1})	30 DAS				60 DAS				90 DAS				Harvest			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm × 10 cm)	5.80	5.77	6.70	**6.09**	19.93	19.40	25.13	**21.49**	22.67	20.60	26.60	**23.29**	23.47	21.40	27.40	**24.09**
2,22,222 (30 cm × 15 cm)	5.77	6.23	6.88	**6.29**	19.68	16.80	22.93	**19.80**	21.60	18.53	24.67	**21.60**	22.40	19.33	25.40	**22.38**
2,22,222 (45 cm × 10 cm)	5.33	5.67	6.77	**5.92**	18.53	18.73	24.60	**20.62**	21.07	19.80	26.00	**22.29**	22.53	20.60	26.80	**23.11**
1,66,666 (30 cm × 20 cm)	5.23	6.33	7.20	**6.26**	17.27	17.53	20.40	**18.40**	20.27	18.60	23.07	**20.64**	21.07	19.27	22.60	**20.98**
Mean	**5.53**	**6.00**	**6.88**	**6.14**	**18.85**	**18.12**	**23.27**	**20.08**	**21.40**	**19.38**	**25.08**	**21.96**	**22.37**	**20.15**	**25.55**	**22.69**
For comparing the two means of	S.Em±		,LS D (0.05)		S.Em±		LSD (0.05)		S.Em±		LSD (0.05)		S.Em±		LSD (0.05)	
Cultivars (cv.)	0.287		NS		0.623		2.45		0.712		2.80		0.826		3.24	
Plant density (PD)	0.218		NS		0.420		1.25		0.352		1.04		0.305		0.91	
PD at the same cv.	0.378		NS		0.728		NS		0.609		NS		0.529		NS	
cv. at the same or different PD	0.435		NS		0.886		NS		0.886		NS		0.944		NS	

Note : NS – Non significant

DAS – Days after sowing

ıble 8 : Number of branches plant^{-1} of groundnut cultivars at different growth stages as influenced by plant density

Plant density (plants ha^{-1})	30 DAS				60 DAS				90 DAS				Harvest			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm × 10 cm)	6.13	5.87	6.47	**6.16**	8.53	7.67	8.07	**8.09**	8.53	9.00	8.67	**8.73**	9.20	9.00	8.73	**8.98**
2,22,222 (30 cm × 15 cm)	6.07	6.27	6.27	**6.20**	7.87	8.33	8.40	**8.20**	9.20	9.40	9.47	**9.36**	9.80	10.20	9.67	**9.89**
2,22,222 (45 cm × 10 cm)	5.87	6.57	6.20	**6.21**	9.00	8.93	8.93	**8.96**	9.07	9.40	9.63	**9.37**	9.87	9.80	9.47	**9.71**
1,66,666 (30 cm × 20 cm)	6.00	6.87	6.47	**6.44**	9.00	9.27	9.47	**9.24**	9.73	9.93	10.20	**9.96**	10.47	10.80	10.33	**10.53**
Mean	**6.20**	**6.39**	**6.35**	**6.25**	**8.60**	**8.55**	**8.72**	**8.62**	**9.13**	**9.43**	**9.49**	**9.35**	**9.83**	**9.95**	**9.55**	**9.78**
For comparing the two means of	S.Em±		LSD (0.05)		S.Em±		LSD (0.05)		S.Em±		LSD (0.05)		S.Em±		LSD (0.05)	
Cultivars (cv.)	0.202		NS		0.229		NS		0.124		NS		0.106		NS	
Plant density (PD)	0.200		NS		0.262		0.78		0.108		0.32		0.104		0.31	
PD at the same cv.	0.346		NS		0.454		NS		0.187		NS		0.180		NS	
cv. at the same or different PD	0.361		NS		0.455		NS		0.204		NS		0.189		NS	

Note : NS – Non significant

DAS – Days after sowing

Plate 2a : Cultivar GPBD 4 at 3,33,333, 2,22,222 (30 cm x 15 cm and 45 cm x 10 cm planting geometry) and 1,66,666 plants ha^{-1}

Plate 2b : Cultivar TAG 24 at 3,33,333, 2,22,222 (30 cm x 15 cm and 45 cm x 15 cm planting geometry) and 1,66,666 plants ha^{-1}

Plate 2c : Cultivar JL 24 at 3,33,333, 2,22,222 (30 cm x 15 cm and 45 cm x 15 cm planting geometry) and 1,66,666 plants ha^{-1}

Plate 3 : Groundnut cultivars (GPBD 4, TAG 24 and JL 24) at harvest

Effect of plant density was significant with respect to number of branches plant^{-1} at all the growth stages except at 30 days after sowing (DAS). Number of branches plant^{-1} decreased with increasing plant density from 1,66,666 to 3,33,333 plants ha^{-1}.

None of the interaction effects were found significant with respect to number of branches plant^{-1}.

4.1.3 Plant spread (cm)
(c.f. Table 9)

Cultivars showed significant difference with respect to plant spread at all the growth stages. Plant spread was maximum in cv. JL 24 (20.25, 34.08, 42.33 and 43.83 cm at 30, 60, 90 DAS and at harvest, respectively) as compared to cv. GPBD 4 and cv. TAG 24.

Effect of plant density was significant with respect to plant spread at all the growth stages. Increase in plant density from 1,66,666 to 3,33,333 plants ha^{-1} decreased the plant spread. Lower plant density recorded maximum plant spread (21.22, 33.33, 40.00 and 41.56 at 30, 60, 90 DAS and at harvest, respectively).

Interaction effects of cultivars and plant density were not significant with respect to plant spread at all the growth stages.

4.1.4 Number of nodules plant^{-1})
(c.f. Table 10)

Number of nodules plant^{-1} differed significantly among groundnut cultivars at 45 and 60 days after sowing (DAS). More number of nodules were noticed in cv. JL 24 (94.00 and 112.85 at 45 and 60 DAS, respectively) as compared to other cultivars (GPBD 4 and TAG 24).

Number of nodules differed significantly with plant density at 45 and 60 DAS. Groundnut grown at a plant density of 1,66,666 plants ha^{-1} recorded more

Table 9 : Plant spread (cm) of groundnut cultivars at different growth stages as influenced by plant density

Plant density (plants ha^{-1})	30 DAS				60 DAS				90 DAS				Harvest			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm × 10 cm)	17.00	16.00	18.33	**17.11**	26.67	28.00	31.67	**28.78**	32.33	34.67	39.33	**35.44**	34.00	36.33	41.33	**37.22**
2,22,222 (30 cm × 15 cm)	18.33	19.00	19.33	**18.89**	29.00	29.00	34.00	**30.67**	35.00	36.00	43.00	**38.00**	36.33	37.67	44.67	**39.56**
2,22,222 (45 cm × 10 cm)	18.67	19.67	20.67	**19.67**	29.33	30.33	34.33	**31.33**	35.33	37.67	42.33	**38.44**	37.67	38.67	44.00	**40.11**
1,66,666 (30 cm × 20 cm)	20.00	21.00	22.67	**21.22**	31.33	32.33	36.33	**33.33**	38.33	37.00	44.67	**40.00**	39.33	40.00	45.33	**41.56**
Mean	**18.50**	**18.92**	**20.25**	19.22	**29.08**	**29.92**	**34.08**	31.03	**35.25**	**36.33**	**42.33**	37.97	**36.83**	**38.17**	**43.83**	39.61
For comparing the two means of	S.Em±			LSD (0.05)	S.Em±			LSD (0.05)	S.Em±			LSD (0.05)	S.Em±			LSD (0.05)
Cultivars (cv.)	0.347			1.36	0.861			3.38	0.576			2.26	0.597			2.35
Plant density (PD)	0.192			0.57	0.615			1.83	0.437			1.30	0.430			1.28
PD at the same cv.	0.333			NS	1.066			NS	0.758			NS	0.745			NS
cv. at the same or different PD	0.451			NS	1.262			NS	0.873			NS	0.879			NS

Note : NS – Non significant

DAS – Days after sowing

Table 10 : Number of nodules $plant^{-1}$ and nodule dry weight (g $plant^{-1}$) of groundnut cultivars at different growth stages as influenced by plant density

Plant density (plants ha^{-1})	Number of nodules $plant^{-1}$								Nodule dry weight (g $plant^{-1}$)							
	45 DAS				60 DAS				45 DAS				60 DAS			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm × 10 cm)	80.80	81.80	83.00	**81.87**	87.33	92.00	109.67	**96.33**	0.052	0.055	0.059	**0.056**	0.108	0.119	0.124	**0.117**
2,22,222 (30 cm × 15 cm)	81.60	83.60	95.67	**86.96**	100.13	106.20	112.07	**106.13**	0.056	0.057	0.068	**0.060**	0.141	0137	0.144	**0.141**
2,22,222 (45 cm × 10 cm)	84.73	84.93	90.80	**86.82**	98.73	97.87	115.53	**104.04**	0.056	0.057	0.064	**0.059**	0.137	0.140	0.137	**0.138**
1,66,666 (30 cm × 20 cm)	87.33	87.13	106.53	**93.67**	113.93	117.00	114.13	**115.02**	0.061	0.061	0.065	**0.062**	0.152	0.151	0.156	**0.153**
Mean	**83.62**	**84.37**	**94.00**	**87.33**	**100.03**	**103.27**	**112.85**	**105.38**	**0.056**	**0.057**	**0.064**	**0.059**	**0.135**	**0.137**	**0.140**	**0.137**
For comparing the two means of	S.Em±			LSD (0.05)	S.Em±			LSD (0.05)	S.Em±			LSD (0.05)	S.Em±			LSD (0.05)
Cultivars (**cv.**)	1.569			6.16	2.302			9.04	0.002			NS	0.003			NS
Plant density (**PD**)	1.863			5.53	2.292			6.81	0.001			0.003	0.003			0.009
PD at the same **cv.**	3.227			NS	3.969			NS	0.001			NS	0.005			NS
cv. at the same or different **PD**	3.205			NS	4.137			NS	0.003			NS	0.005			NS

Note : NS – Non significant

DAS – Days after sowing

number of nodules plant^{-1} (93.67 and 115.02 at 45 and 60 DAS, respectively) as compared to other densities.

Interaction effects of cultivars and plant density were not significant with respect to number of nodules plant^{-1} at 45 and 60 DAS.

4.1.5 Nodule dry weight (g plant^{-1})

(c.f. Table 10)

Cultivars did not differ significantly with respect to nodule dry weight plant^{-1} at 45 and 60 days after sowing (DAS).

Effect of plant density was significant with respect to nodule dry weight plant^{-1} at 45 and 60 DAS. Increase in plant density from 1,66,666 to 3,33,333 plants ha^{-1} decreased the nodule dry weight. Lower plant density recorded more nodule dry weight (0.062 and 0.153 g at 45 and 60 DAS, respectively).

Interaction effects of cultivars and plant density were not significant with respect to nodule dry weight at 45 and 60 DAS.

4.2 Growth Parameters

4.2.1 Leaf dry matter (g plant^{-1})

(c.f. Table 11)

Cultivars showed significant difference with respect to leaf dry matter plant^{-1} at all the growth stages. Cultivar JL 24 recorded higher leaf dry matter (1.364, 9.392, 11.242 and 10.092 g at 30, 60, 90 DAS and at harvest, respectively) compared to cv. GPBD 4 and cv. TAG 24.

Effect of plant density was significant with respect to leaf dry matter plant^{-1} at all the growth stages. Leaf dry matter decreased with increasing plant density from 1,66,666 to 3,33,333 plants ha^{-1}. Groundnut grown at a plant density of 1,66,666 plants ha^{-1} recorded higher leaf dry matter (1.437, 9.056, 11.178 and 9.600 g at 30, 60, 90 DAS and at harvest, respectively).

Table 11 : Leaf dry matter (g $plant^{-1}$) of groundnut cultivars at different growth stages as influenced by plant density

Plant density (plants ha^{-1})	30 DAS				60 DAS				90 DAS				Harvest			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm × 10 cm)	1.047	1.157	1.233	**1.146**	7.400	8.100	8.933	**8.144**	9.167	9.767	10.733	**9.889**	8.367	8.400	9.733	**8.833**
2,22,222 (30 cm × 15 cm)	1.243	1.230	1.310	**1.261**	7.867	8.533	9.367	**8.589**	9.433	10.567	10.967	**10.322**	8.400	9.267	10.100	**9.256**
2,22,222 (45 cm × 10 cm)	1.307	1.283	1.400	**1.330**	7.833	8.633	9.467	**8.644**	10.000	10.400	11.400	**10.600**	8.633	9.333	10.067	**9.344**
1,66,666 (30 cm × 20 cm)	1.350	1.447	1.513	**1.437**	8.467	8.900	9.800	**9.056**	10.567	11.100	11.867	**11.178**	8.833	9.500	10.467	**9.600**
Mean	**1.237**	**1.279**	**1.364**	**1.293**	**7.892**	**8.542**	**9.392**	**8.608**	**9.792**	**10.458**	**11.242**	**10.497**	**8.558**	**9.125**	10.092	**9.258**
For comparing the two means of	S.Em±		LSD (0.05)		S.Em±		LSD (0.05)		S.Em±		LSD (0.05)		S.Em±		LSD (0.05)	
Cultivars (cv.)	0.014		0.055		0.118		0.462		0.159		1.032		0.150		0.590	
Plant density (PD)	0.024		0.073		0.119		0.354		0.132		0.536		0.115		0.341	
PD at the same cv.	0.042		NS		0.207		NS		0.228		NS		0.199		NS	
cv. at the same or different PD	0.039		NS		0.214		NS		0.253		NS		0.228		NS	

Note : NS – Non significant

DAS – Days after sowing

Interaction effects of cultivars and plant density were not significant with respect to leaf dry matter.

4.2.2 Stem dry matter (g plant^{-1})

(c.f. Table 12)

Cultivars differed significantly with respect to stem dry matter plant^{-1} at 60 and 90 days after sowing. Stem dry matter of cv. JL 24 was more (10.117 and 12.383 g at 60 and 90 DAS, respectively) as compared to cv. GPBD 4 and cv. TAG 24 .

The effect of plant density was significant with respect to stem dry matter plant^{-1} at all the growth stages. Stem dry matter plant^{-1} decreased with increasing plant density. The extent of reduction in stem dry matter plant^{-1} due to increase in plant density from 1,66,666 to 3,33,333 plants ha^{-1} was 16.45, 8.73, 8.24 and 8.33 per cent at 30, 60, 90 DAS and at harvest, respectively.

Interaction effects of cultivars and plant density were not significant with respect to stem dry matter plant^{-1}.

4.2.3 Reproductive dry matter (g plant^{-1})

(c.f. Table 13)

Dry matter of reproductive parts differed significantly with cultivars at all the growth stages (60, 90 DAS and at harvest). Reproductive dry matter plant^{-1} was highest in cv. TAG 24 (3.281, 26.708 and 28.433 g at 60, 90 DAS and at harvest, respectively) as compared to cv. GPBD 4 and cv. JL 24.

The effect of plant density on reproductive dry matter was significant at all the growth stages. Increasing plant density from 1,66,666 to 3,33,333 plants ha^{-1} decreased the reproductive dry matter plant^{-1}. Lower plant density recorded higher reproductive dry matter plant^{-1} (3.414, 28.989 and 30.556 g at 60, 90 DAS and at harvest, respectively).

Interaction effects of cultivars and plant density were not significant with respect to reproductive dry matter plant^{-1}.

Table 12 : Stem dry matter (g plant^{-1}) of groundnut cultivars at different growth stages as influenced by plant density

Plant density (plants ha^{-1})	30 DAS				60 DAS				90 DAS				Harvest			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm × 10 cm)	0.937	1.070	1.087	**1.031**	8.800	8.533	9.500	**8.944**	10.967	11.567	12.000	**11.511**	11.500	11.733	12.733	**11.989**
2,22,222 (30 cm × 15 cm)	1.097	1.097	1.127	**1.107**	8.567	9.233	9.833	**9.211**	11.333	11.567	11.433	**11.444**	12.033	12.400	12.467	**12.300**
2,22,222 (45 cm × 10 cm)	1.097	1.113	1.180	**1.130**	8.833	9.133	10.467	**9.478**	11.300	12.400	13.167	**12.289**	12.267	12.700	13.167	**12.711**
1,66,666 (30 cm × 20 cm)	1.193	1.197	1.313	**1.234**	9.100	9.633	10.667	**9.800**	12.400	12.300	12.933	**12.544**	13.133	13.067	13.033	**13.078**
Mean	**1.081**	**1.119**	**1.177**	**1.126**	**8.825**	**9.133**	**10.117**	**9.358**	**11.500**	**11.958**	**12.383**	**11.947**	**12.233**	**12.475**	**12.850**	**12.519**
For comparing the two means of	S.Em±		LSD (0.05)		S.Em±		LSD (0.05)		S.Em±		LSD (0.05)		S.Em±		LSD (0.05)	
Cultivars (cv.)	0.031		NS		0.082		0.324		0.142		0.558		0.151		NS	
Plant density (PD)	0.017		0.051		0.131		0.390		0.269		0.800		0.207		0.614	
PD at the same cv.	0.029		NS		0.227		NS		0.467		NS		0.358		NS	
cv. at the same or different PD	0.041		NS		0.214		NS		0.428		NS		0.345		NS	

Note : NS – Non significant

DAS – Days after sowing

Table 13 : Reproductive dry matter (g plant^{-1}) of groundnut cultivars at different growth stages as influenced by plant density

Plant density (plants ha^{-1})	60 DAS				90 DAS				Harvest			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm × 10 cm)	2.517	2.997	2.763	**2.759**	20.300	20.600	20.633	**20.511**	21.800	22.133	22.333	**22.089**
2,22,222 (30 cm × 15 cm)	3.090	3.237	2.970	**3.099**	24.033	28.067	25.300	**25.800**	26.467	30.067	27.467	**28.000**
2,22,222 (45 cm × 10 cm)	2.960	3.127	2.880	**2.989**	24.300	27.300	23.600	**25.067**	26.000	29.667	25.533	**27.067**
1,66,666 (30 cm × 20 cm)	3.327	3.763	3.153	**3.414**	29.733	30.867	26.367	**28.989**	31.067	31.867	28.733	**30.556**
Mean	**2.973**	**3.281**	**2.942**	**3.065**	**24.592**	**26.708**	**23.975**	**25.092**	**26.333**	**28.433**	**26.017**	**26.928**
For comparing the two means of	S.Em±		LSD (0.05)		S.Em±		LSD (0.05)		S.Em±		LSD (0.05)	
Cultivars (cv.)	0.060		0.236		0.499		1.961		0.446		1.750	
Plant density (PD)	0.039		0.115		0.516		1.532		0.614		1.824	
PD at the same cv.	0.067		NS		0.593		NS		1.064		NS	
cv. at the same or different PD	0.084		NS		0.921		NS		1.024		NS	

Note : NS – Non significant

DAS – Days after sowing

4.2.4 Total dry matter (g $plant^{-1}$)
(c.f. Table 14)

Cultivars differed significantly with respect to total dry matter $plant^{-1}$ (TDMP) at all the growth stages. TDMP was highest in cv. JL 24 at 30 and 60 DAS (2.540 and 22.450, respectively). Whereas cv. TAG 24 recorded significantly higher TDMP at 90 DAS and at harvest (49.125 and 50.033 g, respectively) compared to cv. GPBD 4 but was on par with cv. JL 24.

The effect of plant density on TDMP was significant at all the growth stages. TDMP increased with decreasing plant density. The extent of reduction in TDMP due to increase in plant density from 1,66,666 to 3,33,333 plants ha^{-1} was 18.46, 10.88, 20.70 and 19.36 per cent at 30, 60, 90 DAS and at harvest, respectively.

None of the interaction effects were found significant with respect to TDMP.

4.2.5 **Dry matter distribution in different plant parts as percentage of total dry matter $plant^{-1}$**
(c.f. Table 15,16, 17 and 18)

Cultivars differed significantly with respect to dry matter distribution in different plant parts at all the growth stages except at 30 days after sowing (DAS). Dry matter distribution in leaf and stem was higher in cv. JL 24 compared to cv. GPBD 4 and cv. TAG 24. Whereas, dry matter distribution in reproductive parts was more in cv. TAG 24 compared to cv. GPBD 4 and cv. JL 24. As growth advanced, the contribution from leaf and stem dry matter towards the total dry matter $plant^{-1}$ of three cultivars tended to decrease. However, the contribution from reproductive dry matter towards the total dry matter at later growth stages tended to increase. At harvest, cv. TAG 24 had greater dry matter contribution in reproductive parts (56.60%) as compared to cv. GPBD 4 (55.69%) and cv. JL 24 (53.03%).

Table 14 : Total dry matter (g plant^{-1}) of groundnut cultivars at different growth stages as influenced by plant density

Plant density (plants ha^{-1})	30 DAS				60 DAS				90 DAS				Harvest			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm × 10 cm)	1.984	2.227	2.320	**2.177**	18.717	19.630	21.196	**19.847**	40.434	41.934	43.366	**41.800**	41.667	42.266	44.799	**42.910**
2,22,222 (30 cm × 15 cm)	2.340	2.327	2.437	**2.368**	19.524	21.003	22.170	**20.899**	44.799	50.201	47.700	**47.566**	46.900	51.734	50.034	**49.556**
2,22,222 (45 cm × 10 cm)	2.404	2.396	2.580	**2.460**	19.626	20.893	22.814	**21.111**	45.600	50.100	48.167	**47.955**	46.900	51.700	48.767	**49.122**
1,66,666 (30 cm × 20 cm)	2.543	2.644	2.826	**2.670**	20.894	22.296	23.620	**22.270**	52.700	54.267	51.167	**52.711**	53.033	54.434	52.233	**53.233**
Mean	**2.317**	**2.398**	**2.540**	**2.419**	**19.690**	**20.955**	**22.450**	**21.031**	**45.833**	**49.125**	**47.600**	**47.536**	**47.125**	**50.033**	**48.958**	**48.705**
For comparing the two means of	S.Em±		LSD (0.05)		S.Em±		LSD (0.05)		S.Em±		LSD (0.05)		S.Em±		LSD (0.05)	
Cultivars (cv.)	0.018		0.072		0.179		0.701		0.568		2.229		0.461		1.811	
Plant density (PD)	0.012		0.062		0.197		0.586		0.521		1.546		0.639		1.899	
PD at the same cv.	0.036		NS		03.342		NS		0.902		NS		1.108		NS	
cv. at the same or different PD	0.036		NS		0.346		NS		0.965		NS		1.064		NS	

Note : NS – Non significant

DAS – Days after sowing

Table 15 : Dry matter distribution in different plant parts of groundnut cultivars as percentage of total dry matter at 30 days after sowing as influenced by plant density

Plant density (plants ha^{-1})	Leaf				Stem			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm × 10 cm)	52.77	51.95	53.15	**52.62**	47.23	48.05	46.85	47.38
2,22,222 (30 cm × 15 cm)	53.12	52.86	53.75	**53.24**	46.88	47.14	46.25	46.76
2,22,222 (45 cm × 10 cm)	54.37	53.55	54.26	**54.06**	45.63	46.45	45.74	45.94
1,66,666 (30 cm × 20 cm)	53.09	54.74	53.54	**53.79**	46.91	45.27	46.46	46.21
Mean	**53.34**	**53.27**	**53.68**	**53.43**	**46.66**	**46.73**	**46.32**	**46.57**

For comparing the two means of	Leaf S.Em±	Leaf LSD (0.05)	Stem S.Em±	Stem LSD (0.05)
Cultivars (cv.)	0.952	NS	0.814	NS
Plant density (PD)	0.722	NS	0.759	NS
PD at the same cv.	1.250	NS	1.314	NS
cv. at the same or different PD	1.441	NS	1.399	NS

Note : NS – Non significant

Table 16 : Dry matter distribution in different plant parts of groundnut cultivars as percentage of total dry matter at 60 days after sowing as influenced by plant density

Plant density (plants ha^{-1})	Leaf				Stem				Reproductive parts			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm × 10 cm)	39.54	41.26	42.14	**40.98**	47.01	43.47	44.82	**45.10**	13.46	15.27	13.04	**13.92**
2,22,222 (30 cm × 15 cm)	40.29	40.63	42.25	**41.06**	43.88	43.96	44.35	**44.06**	15.83	15.41	13.40	**14.88**
2,22,222 (45 cm × 10 cm)	39.91	41.32	41.50	**40.91**	45.01	43.71	45.88	**44.87**	15.08	14.97	12.62	**14.22**
1,66,666 (30 cm × 20 cm)	40.53	39.92	41.49	**40.65**	43.55	43.20	45.16	**43.97**	15.92	16.88	13.35	**15.38**
Mean	**40.07**	**40.78**	**41.85**	**40.90**	**44.86**	**43.59**	**45.05**	**44.50**	**15.07**	**15.63**	**13.10**	**14.60**
For comparing the two means of	S.Em±		LSD (0.05)		S.Em±		LSD (0.05)		S.Em±		LSD (0.05)	
Cultivars (cv.)	0.409		NS		0.206		0.81		0.306		1.20	
Plant density (**PD**)	0.415		NS		0.450		NS		0.188		0.56	
PD at the same **cv.**	0.719		NS		0.779		NS		0.325		0.97	
cv. at the same or different **PD**	0.745		NS		0.705		NS		0.416		1.24	

Note : NS – Non significant

Table 17 : Dry matter distribution in different plant parts of groundnut cultivars as percentage of total dry matter at 90 days after sowing as influenced by plant density

Plant density (plants ha^{-1})	Leaf				Stem				Reproductive parts			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm × 10 cm)	22.67	23.29	24.75	**23.57**	27.12	27.58	27.67	**27.46**	50.21	49.13	47.58	**48.97**
2,22,222 (30 cm × 15 cm)	21.05	21.05	22.99	**21.70**	25.30	23.04	23.97	**24.10**	53.65	55.91	53.04	**54.20**
2,22,222 (45 cm × 10 cm)	21.93	20.76	23.67	**22.12**	24.78	24.75	27.34	**25.62**	53.29	54.49	48.99	**52.26**
1,66,666 (30 cm × 20 cm)	20.05	20.45	23.19	**21.23**	23.53	22.67	25.28	**23.83**	56.42	56.88	51.33	**54.94**
Mean	**21.43**	**21.39**	**23.65**	**22.16**	**25.18**	**24.51**	**26.06**	**25.25**	**53.39**	**54.10**	**50.29**	**52.59**
For comparing the two means of	S.Em±		LSD (0.05)		S.Em±		LSD (0.05)		S.Em±		LSD (0.05)	
Cultivars **(cv.)**	0.329		1.29		0.479		NS		0.381		1.50	
Plant density **(PD)**	0.401		1.19		0.542		1.61		0.690		2.05	
PD at the same **cv.**	0.695		NS		0.939		NS		1.196		NS	
cv. at the same or different **PD**	0.686		NS		0.944		NS		1.104		NS	

Note : NS – Non significant

Table 18 : Dry matter distribution in different plant parts of groundnut cultivars as percentage of total dry matter at harvest as influenced by plant density

Plant density (plants ha^{-1})	Leaf				Stem				Reproductive parts			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm × 10 cm)	20.08	19.87	21.73	**20.56**	27.60	27.76	28.42	**27.93**	52.32	52.37	49.85	**51.51**
2,22,222 (30 cm × 15 cm)	17.91	17.91	20.19	**18.67**	25.66	23.97	24.92	**24.85**	56.43	58.12	54.89	**56.48**
2,22,222 (45 cm × 10 cm)	18.41	18.05	20.64	**19.03**	26.16	24.57	27.00	**25.91**	55.43	57.38	52.36	**55.06**
1,66,666 (30 cm × 20 cm)	16.66	17.45	20.04	**18.05**	24.76	24.01	24.95	**24.57**	58.58	58.54	55.01	**57.38**
Mean	**18.26**	**18.32**	**20.65**	**19.08**	**26.05**	**25.08**	**26.32**	**25.81**	**55.69**	**56.60**	**53.03**	**55.11**
For comparing the two means of	S.Em±		LSD (0.05)		S.Em±		LSD (0.05)		S.Em±		LSD (0.05)	
Cultivars (cv.)	0.413		1.62		0.342		NS		0.415		1.63	
Plant density (PD)	0.389		1.15		0.553		1.64		0.750		2.23	
PD at the same cv.	0.673		NS		0.959		NS		1.300		NS	
cv. at the same or different PD	0.717		NS		0.898		NS		1.200		NS	

Note : NS – Non significant

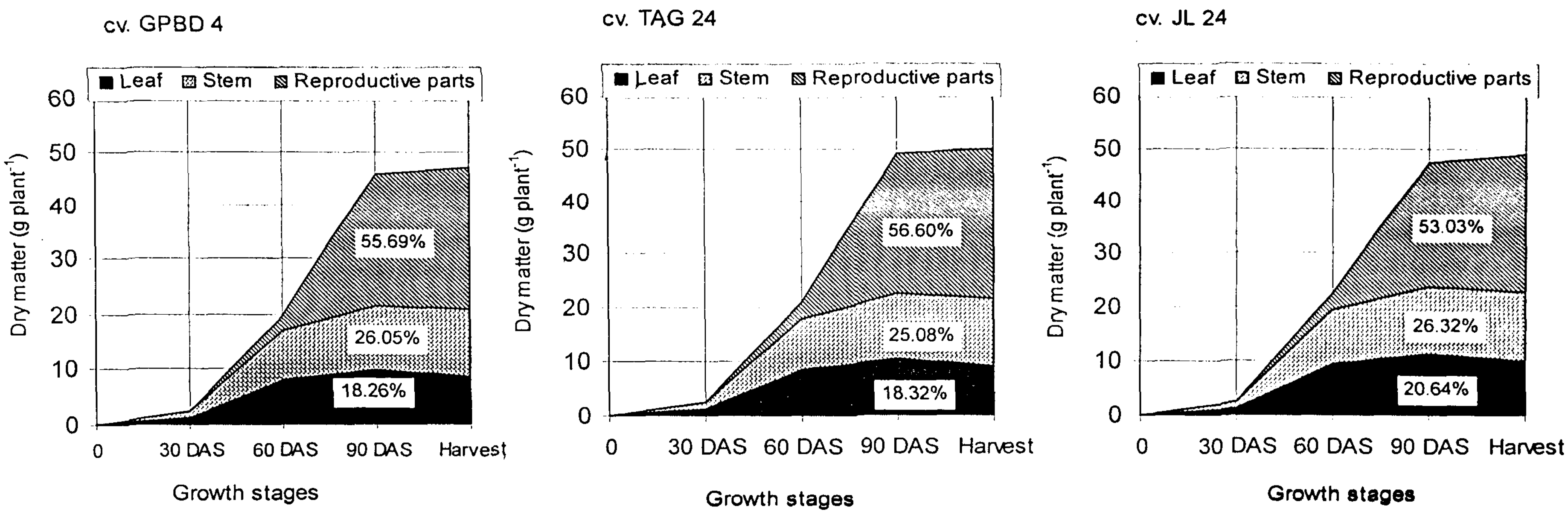


Fig. 4a. Dry matter production (g $plant^{-1}$) and its distribution in different plant parts of groundnut cultivars at different growth stages

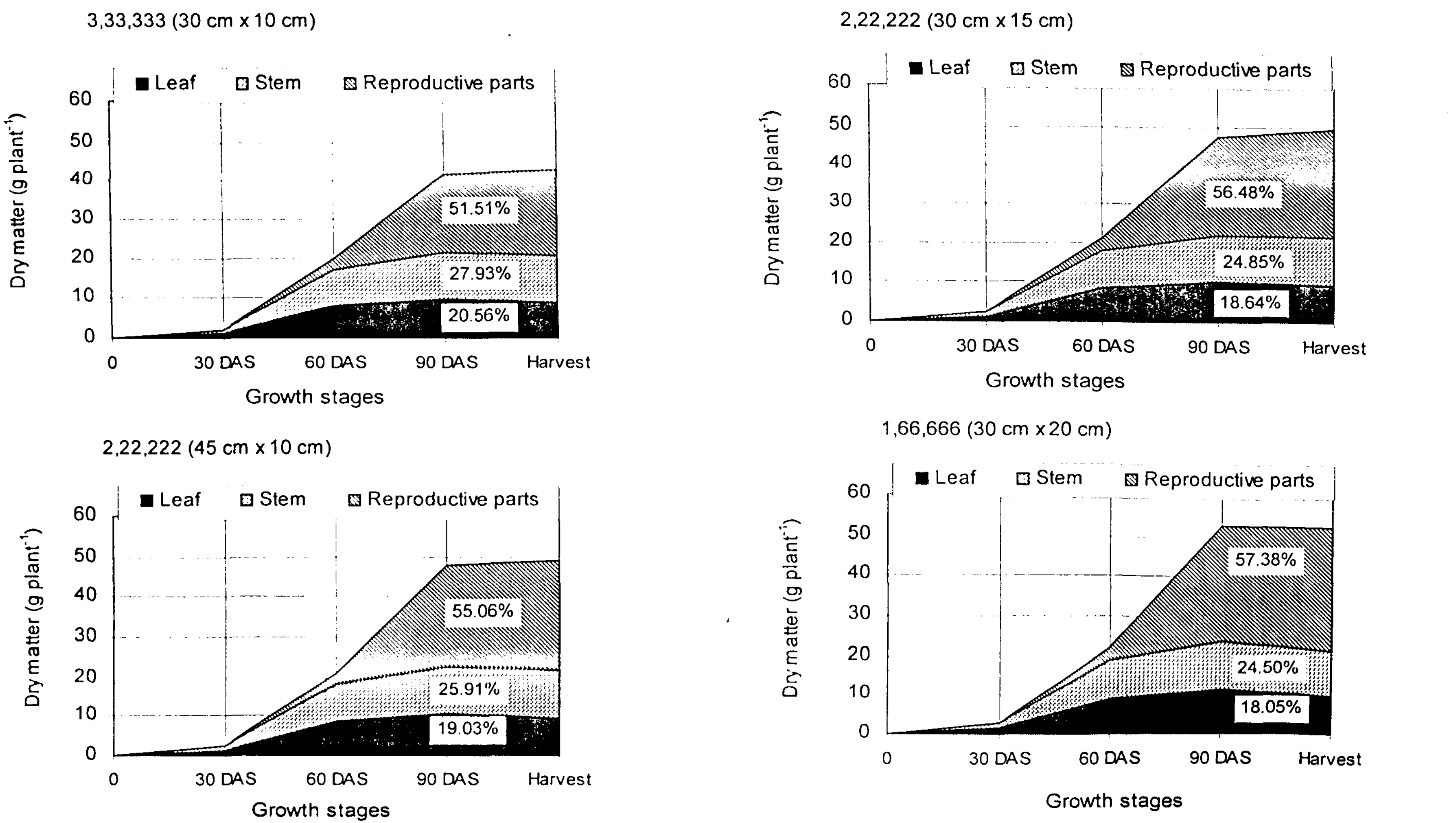


Fig. 4b. Effect of plant density on dry matter production (g plant^{-1}) and its distribution in different plant parts of groundnut at different growth stages

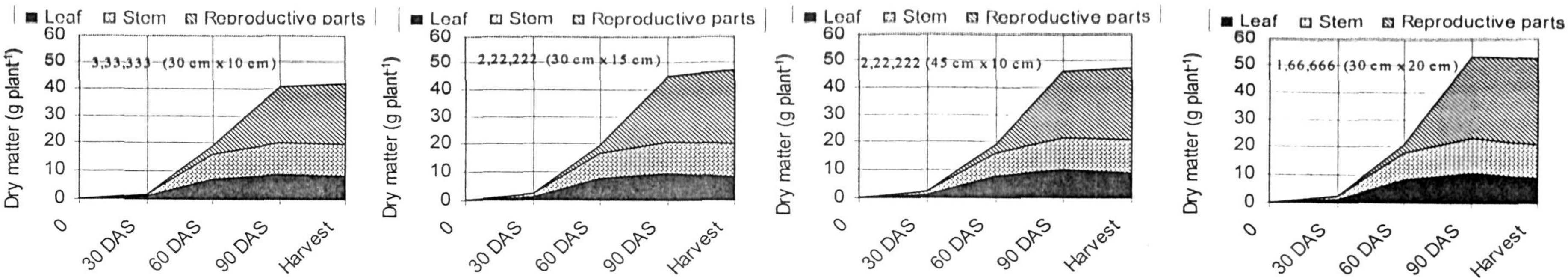


Fig. 4c. Effect of plant density on dry matter production (g plant^{-1}) and its distribution in different parts of cv. GPBD 4

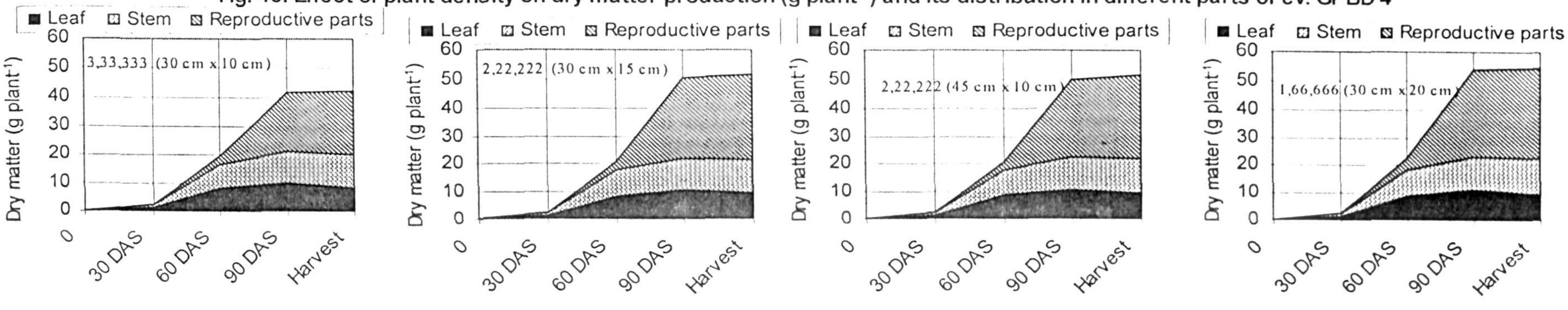


Fig. 4c. Effect of plant density on dry matter production (g plant^{-1}) and its distribution in different parts of cv. TAG 24

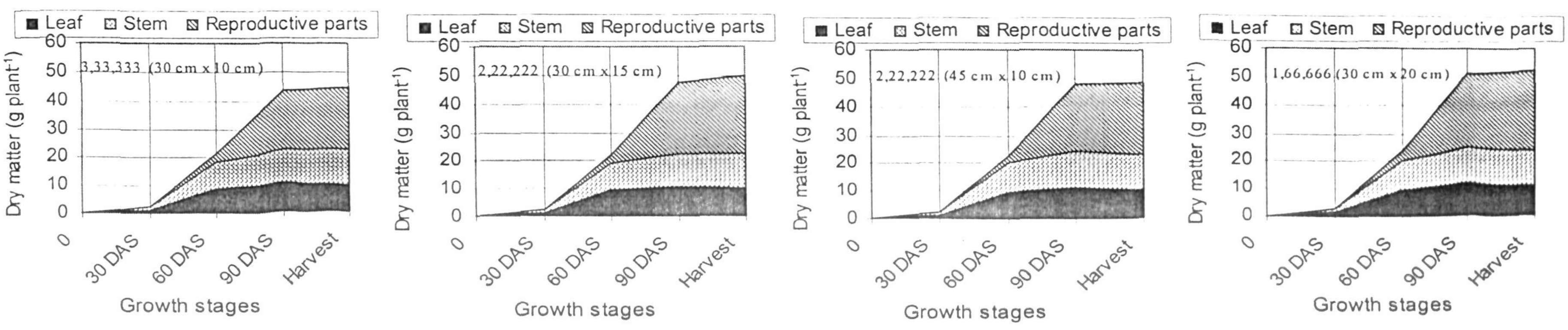


Fig. 4c. Effect of plant density on dry matter production (g plant^{-1}) and its distribution in different parts of cv. JL 24

Effect of plant density was significant with respect to dry matter distribution. As the plant density increased (1,66,666 to 3,33,333 plants ha^{-1}), the dry matter distribution in different plant parts (leaf, stem and reproductive parts) tended to decrease.

Interaction effects of cultivars and plant density were significant with respect to dry matter distribution in reproductive parts at 60 DAS. Cultivar TAG 24 maximized its dry matter distribution in reproductive parts (16.88%) at a plant density of 1,66,666 plants ha^{-1}. However, cv. GPBD and cv. JL 24 maximized their dry matter distribution in reproductive parts at a plant density of 2,22,222 plants ha^{-1} (15.83 and 13.40%, respectively) with a planting geometry of 30 cm × 15 cm.

4.2.6 Leaf area plant^{-1} (dm^2)

(c.f. Table 19)

Cultivars differed significantly with respect to leaf area plant^{-1} at all the growth stages. Leaf area plant^{-1} was higher in cv. JL 24 (2.44,14.28, 16.30 and 14.65 dm^2 at 30, 60, 90 DAS and at harvest, respectively) compared to cv. GPBD 4 and cv. JL 24.

Effect of plant density was significant with respect to leaf area plant^{-1} at all the growth stages. Lower plant density (1,66,666 plants ha^{-1}) recorded higher leaf area plant^{-1} (2.57, 13.80, 16.22 and 13.93 dm^2 at 30, 60, 90 DAS and hat harvest, respectively) compared to other densities (2,22,222 and 3,33,333 plants ha^{-1}).

Interaction effects of cultivars and plant density were not significant with respect to leaf area plant^{-1}.

4.2.7 Leaf area index (LAI)

(c.f. Table 20)

Cultivars differed significantly with respect to LAI at all the growth stages. Cultivar JL 24 recorded higher LAI (0.566, 3.339, 3.819 and 3.436 at 30, 60,

Table 19 : Leaf area plant^{-1} (dm^2) of groundnut cultivars at different growth stages as influenced by plant density

Plant density (plants ha^{-1})	30 DAS				60 DAS				90 DAS				Harvest			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm x 10 cm)	1.87	2.07	2.21	**2.05**	11.28	12.34	13.47	**12.36**	13.30	14.17	15.51	**14.33**	12.14	12.19	14.13	**12.82**
2,22,222 (30 cm x 15 cm)	2.23	2.20	2.34	**2.26**	12.02	13.00	14.27	**13.10**	13.69	15.34	15.92	**14.98**	12.19	13.45	14.66	**13.43**
2,22,222 (45 cm x 10 cm)	2.34	2.30	2.51	**2.38**	11.94	13.13	14.43	**13.16**	14.51	15.09	16.55	**15.38**	12.53	13.55	14.61	**13.56**
1,66,666 (30 cm x 20 cm)	2.42	2.59	2.71	**2.57**	12.90	13.56	14.94	**13.80**	15.33	16.11	17.23	**16.22**	12.82	13.79	15.19	**13.93**
Mean	**2.21**	**2.29**	**2.44**	**2.32**	**12.04**	**13.01**	**14.28**	**13.11**	**14.21**	**15.18**	**16.30**	**15.23**	**12.42**	**13.24**	**14.65**	**13.44**
For comparing the two means of	S.Em±			LSD (0.05)	S.Em±			LSD (0.05)	S.Em±			LSD (0.05)	S.Em±			LSD (0.05)
Cultivars **(cv.)**	0.025			0.10	0.172			0.68	0.231			0.91	0.218			0.86
Plant density **(PD)**	0.044			0.13	0.181			0.54	0.191			0.57	0.167			0.50
PD at the same **cv.**	0.077			NS	0.313			NS	0.331			NS	0.289			NS
cv. at the same or different **PD**	0.071			NS	0.321			NS	0.368			NS	0.331			NS

Note : NS – Non significant

DAS – Days after sowing

Table 20 : Leaf area index (LAI) of groundnut cultivars at different growth stages as influenced by plant density

Plant density (plants ha^{-1})	30 DAS				60 DAS				90 DAS				Harvest			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm × 10 cm)	0.623	0.689	0.735	0.682	3.759	4.114	4.490	4.121	4.434	4.724	5.193	4.784	4.047	4.064	4.708	4.273
2,22,222 (30 cm × 15 cm)	0.494	0.488	0.520	0.501	2.664	2.889	3.171	2.908	3.047	3.408	3.536	3.330	2.708	2.988	3.257	2.985
2,22,222 (45 cm × 10 cm)	0.519	0.510	0.556	0.529	2.652	2.923	3.205	2.927	3.225	3.354	3.676	3.418	2.785	3.010	3.245	3.013
1,66,666 (30 cm × 20 cm)	0.402	0.432	0.451	0.428	2.150	2.260	2.489	2.300	2.555	2.685	2.871	2.704	2.136	2.297	2.532	2.322
Mean	**0.509**	**0.530**	**0.566**	**0.535**	**2.806**	**3.047**	**3.339**	**3.064**	**3.315**	**3.543**	**3.819**	**3.559**	**2.919**	**3.090**	**3.436**	**3.148**

For comparing the two means of	30 DAS S.Em±	30 DAS LSD (0.05)	60 DAS S.Em±	60 DAS LSD (0.05)	90 DAS S.Em±	90 DAS LSD (0.05)	Harvest S.Em±	Harvest LSD (0.05)
Cultivars (cv.)	0.004	0.015	0.038	0.148	0.064	0.253	0.052	0.206
Plant density (PD)	0.009	0.027	0.041	0.122	0.061	0.181	0.041	0.121
PD at the same cv.	0.016	NS	0.071	NS	0.105	NS	0.070	NS
cv. at the same or different PD	0.014	NS	0.073	NS	0.112	NS	0.081	NS

Note : NS – Non significant

DAS – Days after sowing

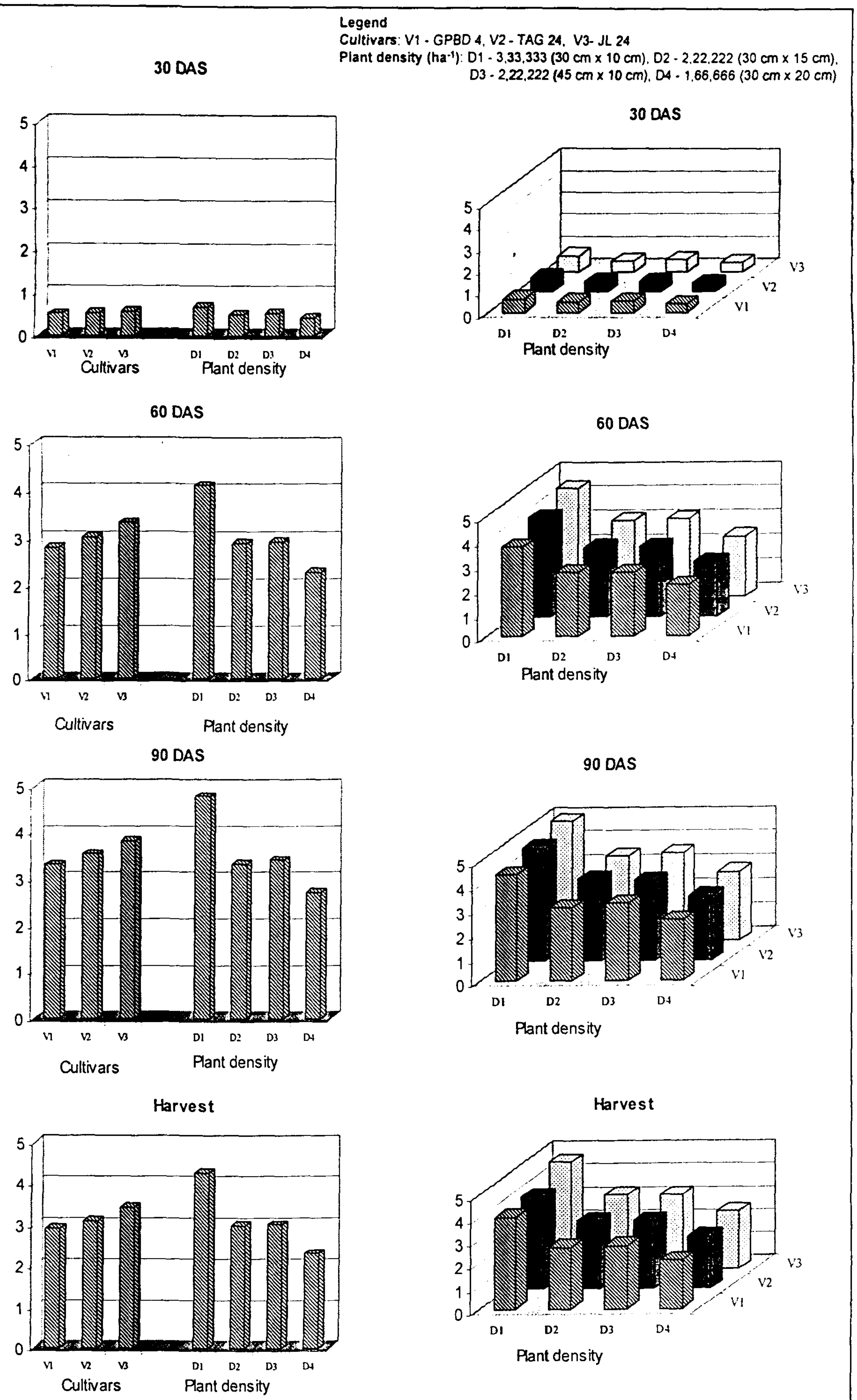


Fig. 5. Leaf area index (LAI) of groundnut cultivars and effect of plant density on LAI at different growth stages of groundnut

90 DAS and at harvest, respectively) compared to other cultivars (GPBD 4 and TAG 24).

Effect of plant density was significant with respect to LAI at all the growth stages. Higher plant density (3,33,333 plants ha^{-1}) resulted in higher LAI (0.682, 4.121, 4.784 and 4.273 at 30, 60, 90 DAS and at harvest, respectively) compared to low and medium densities (1,66,666 and 2,22,222 plants ha^{-1}, respectively).

Interaction effects of cultivars and plant density were not significant with respect to LAI at all the growth stages.

4.3 Yield and yield components

4.3.1 Number of developed pods plant^{-1}

(c.f. Table 21)

Cultivars differed significantly with respect to number of developed pods plant^{-1}. Number of developed pods plant^{-1} were higher in cv. GPBD 4 (23.40) compared to cv. TAG 24 (20.75) and cv. JL 24 (19.67).

Effect of plant density was significant with respect to number of developed pods plant^{-1}. Number of developed pods plant^{-1} decreased with increase in plant density 1,66,666 to 3,33,333 plants ha^{-1}. Lower plant density recorded more number of developed pods plant^{-1} (23.67) compared to medium and higher plant density (2,22,222 and 3,33,333 plants ha^{-1}, respectively).

None of the interaction effects were found significant with respect to number of developed pods plant^{-1}.

4.3.2 Number of undeveloped pods plant^{-1}

(c.f. Table 21)

Difference in number of undeveloped pods plant^{-1} was significant among the cultivars. Cultivar GPBD 4 recorded 29.51 and 33.40 per cent higher number of undeveloped pods plant^{-1} compared to cv. TAG 24 and cv. JL 24, respectively.

Table 21 : Number of developed pods plant^{-1}, number of undeveloped pods plant^{-1} and total number of pods plant^{-1} of groundnut cultivars as influenced by plant density

Plant density (plants ha^{-1})	Number of developed pods plant^{-1}				Number of undeveloped pods plant^{-1}				Total number of pods plant^{-1}			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm × 10 cm)	20.87	18.07	18.20	**19.04**	5.27	3.87	3.47	**4.20**	26.14	21.94	21.67	**23.25**
2,22,222 (30 cm × 15 cm)	24.33	21.73	20.33	**22.13**	5.27	3.60	3.07	**3.98**	29.60	25.33	23.40	**26.11**
2,22,222 (45 cm × 10 cm)	20.93	21.40	18.40	**20.24**	5.33	3.73	4.00	**4.36**	26.26	25.13	22.40	**24.59**
1,66,666 (30 cm × 20 cm)	27.47	21.80	21.73	**23.67**	4.73	3.33	3.20	**3.76**	32.20	25.13	24.93	**27.42**
Mean	**23.40**	**20.75**	**19.67**	**21.27**	**5.15**	**3.63**	**3.43**	**4.07**	**28.55**	**24.38**	**23.10**	**25.34**
For comparing the two means of	S.Em±		LSD (0.05)		S.Em±		LSD (0.05)		S.Em±		LSD (0.05)	
Cultivars (cv.)	0.669		2.63		0.096		0.38		0.559		2.35	
Plant density (**PD**)	0.866		2.57		0.295		NS		0.917		2.72	
PD at the same **cv.**	1.501		NS		0.511		NS		1.589		NS	
cv. at the same or different **PD**	1.462		NS		0.453		NS		1.501		NS	

Note : NS – Non significant

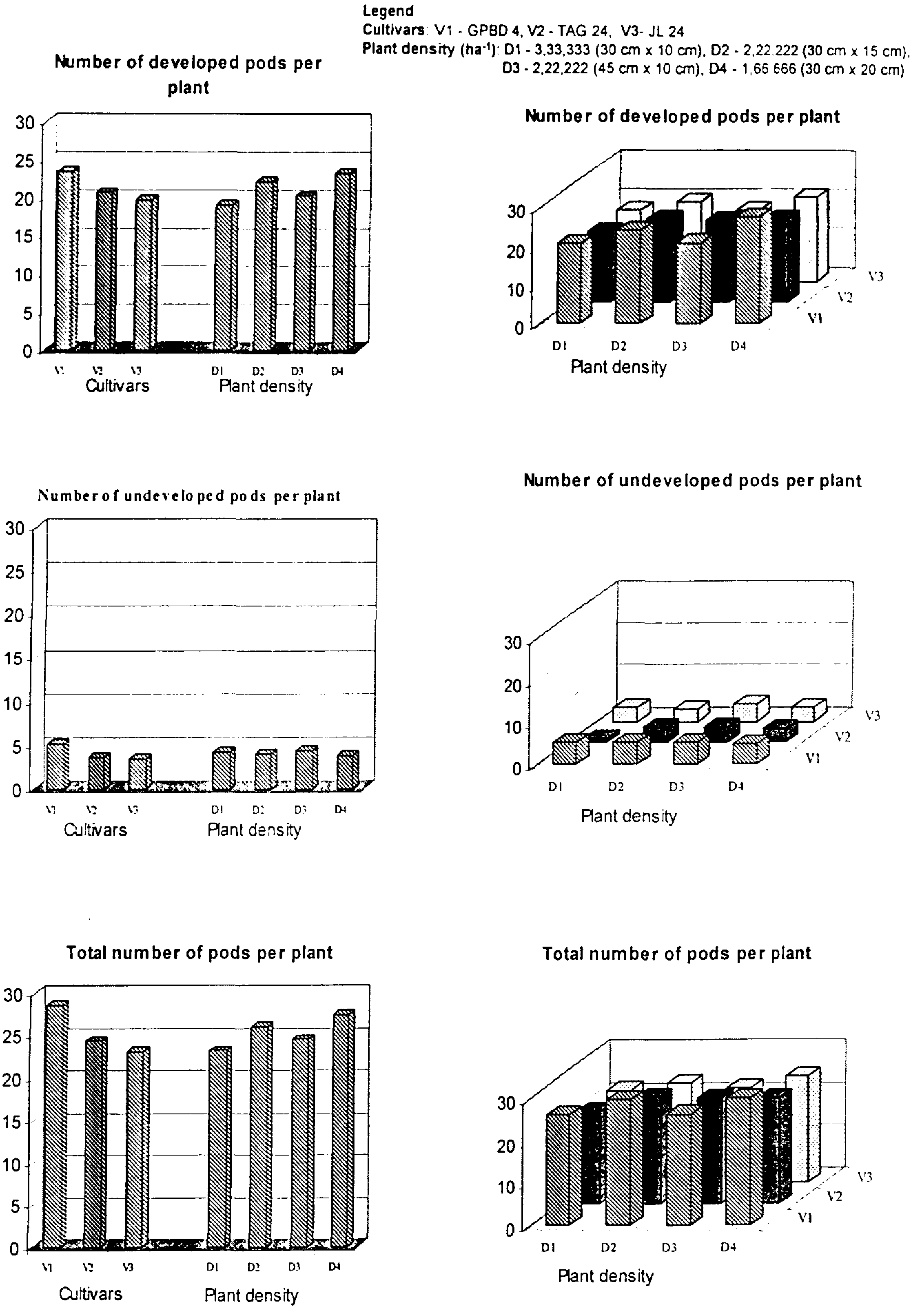


Fig. 6. Effect of plant density on number of developed pods per plant, number of undeveloped pods per plant and total number of pods per plant of groundnut cultivars

Plant density failed to exert significant influence on number of undeveloped pods plant^{-1}. However, number of undeveloped pods plant^{-1} increased from 3.76 to 4.20 with increasing plant density from 1,66,666 to 3,33,333 plants ha^{-1}.

Interaction effects of cultivars and plant density were not significant with respect to number of undeveloped pods plant^{-1}.

4.3.3 Total number of pods plant^{-1}
(c.f. Table 21)

Cultivars differed significantly with respect to total number of pods plant^{-1}. Total number of pods plant^{-1} were 14.61 and 19.09 per cent higher in cv. GPBD 4 compared to cv. TAG 24 and cv. JL 24, respectively.

Effect of plant density on total number of pods plant^{-1} was significant. Total number of pods plant^{-1} decreased with increasing plant density from 1,66,666 to 3,33,333 plants ha^{-1}. Lower plant density produced 4.78, 10.36 per cent more pods over medium and 15.21 per cent over high plant density.

Interaction effects of cultivars and plant density were not significant with respect to total number of pods plant^{-1}.

4.3.4 Dry pod weight plant^{-1} (g)
(c.f. Table 22)

Cultivars differed significantly with respect to dry pod weight plant^{-1}. Dry pod weight plant^{-1} of cv. TAG 24 was 7.39 and 8.50 per cent higher over cv. GPBD 4 and cv. JL 24, respectively.

Dry pod weight plant^{-1} was significantly influenced by plant density. Dry pod weight plant^{-1} decreased due to increase in plant density from 1,66,666 to 3,33,333 plants ha^{-1}. Lower plant density produced higher dry pod weight (30.556 g) compared to medium (27.067 and 28.000 g) and high plant density (22.089 g).

Interaction effects of cultivars and plant density were not significant with respect to dry pod weight plant^{-1}.

4.3.5 Dry pod yield (kg ha^{-1})

(c.f. Table 22)

Cultivars showed significant difference in dry pod yield. Among the cultivars, cv. TAG 24 recorded 3.16 and 10.68 per cent higher dry pod yield over cv. GPBD 4 (4753 kg ha^{-1}) and cv. JL 24 (4384 kg), respectively.

Effect of plant density was significant with respect to dry pod yield. Higher plant density produced 5.27 to 13.25 per cent higher dry pod yield compared to medium plant densities (4379 to 4782 kg ha^{-1}) and 10.52 per cent compared to lower plant density (4517 kg ha^{-1}).

Cultivars TAG 24 maximized its dry pod yield ha^{-1} (5509 kg ha^{-1}) at a plant density of 3,33,333 plants ha^{-1}. While cv. GPBD 4 produced higher dry pod yield (5191 kg ha^{-1}) at a plant density of 2,22,222 plants ha^{-1} with a planting geometry of 30 cm × 15 cm. Whereas, cv. JL 24 produced higher dry pod yield ha^{-1} (4489 kg ha^{-1}) at a plant density of 2,22,222 plants ha^{-1} with a planting geometry of 45 cm × 10 cm.

4.3.6 Kernel yield (kg ha^{-1})

(c.f. Table 22)

Groundnut cultivars differed significantly with respect to kernel yield. Cultivar TAG 24 produced 2.39 and 12.09 per cent higher kernel yield over cv. GPBD 4 (3347 kg) and cv. JL 24 (3016 kg), respectively.

Effect of plant density was significant with respect to kernel yield. Higher plant density produced higher kernel yield (3495 kg) compared to medium (2968 to 3338 kg ha^{-1}) and lower plant density (3256 kg ha^{-1}).

Cultivar TAG 24 produced higher kernel yield (3861 kg) at a plant density of 3,33,333 plants ha^{-1} compared to other plant densities. However, cv. GPBD 4 maximized the kernel yield (3716 kg ha^{-1}) at a plant density of 2,22,222 plants ha^{-1}

Table 22 : Dry pod weight plant^{-1} (g), dry pod yield (kg ha^{-1}), kernel yield (kg ha^{-1}) and dry haulm yield (kg ha^{-1})of groundnut cultivars as influenced by plant density

Plant density (plants ha^{-1})	Dry pod weight plant^{-1} (g)				Dry pod yield (kg ha^{-1})				Kernel yield (kg ha^{-1})				Dry haulm yield (kg ha^{-1})			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mea
3,33,333 (30 cm × 10 cm)	21.800	22.133	22.333	**22.089**	5161	5509	4476	**5048**	3597	3861	3026	**3495**	5633	5453	5607	556
2,22,222 (30 cm × 15 cm)	26.467	30.067	27.467	**28.000**	5191	5043	4112	**4782**	3716	3532	2766	**3338**	5453	5375	5658	549
2,22,222 (45 cm × 10 cm)	26.000	29.667	25.533	**27.067**	4218	4430	4489	**4379**	2811	3003	3088	**2968**	5864	5195	5556	553
1,66,666 (30 cm × 20 cm)	**31.067**	**31.867**	**28.733**	**30.556**	**4442**	**4649**	**4461**	**4517**	**3263**	**3320**	**3185**	**3256**	**5273**	**5144**	**5736**	538
Mean	**26.333**	**28.433**	**26.017**	**29.928**	**4753**	**4908**	**4384**	**4682**	**3347**	**3429**	**3016**	**3264**	5556	5292	5639	5496

For comparing the two means of	S.Em±	LSD (0.05)	S.Em±	LSD (0.05)	S.Em±	LSD (0.05)	S.Em±	LSD (0.05)
Cultivars (cv.)	0.446	1.750	35.402	139	52.345	206	63.624	250
Plant density (PD)	0.614	1.824	65.096	193	73.425	218	75.884	NS
PD at the same cv.	1.064	NS	112.749	335	127.176	378	131.435	NS
cv. at the same or different PD	1.024	NS	103.863	309	121.944	362	130.401	NS

Note : NS – Non significant

DAS – Days after sowing

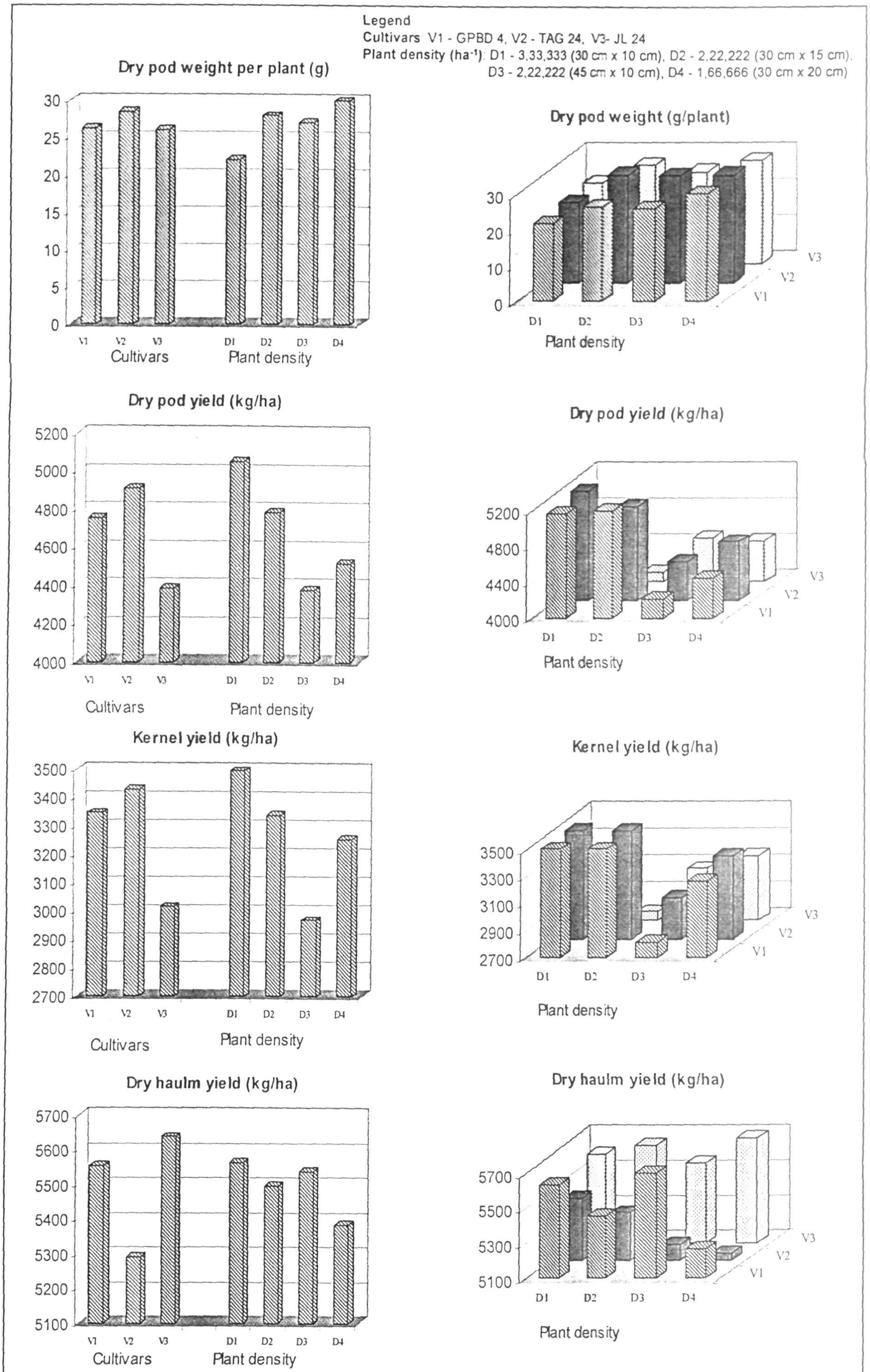


Fig. 7. Effect of plant density on dry pod weight per plant (g), dry pod yield (kg/ha), kernel yield (kg/ha) and dry haulm yield (kg/ha) of groundnut cultivars

Plate 4 : Dry pods of groundnut cultivars (GPBD 4, TAG 24 and JL 24)

Plate 5 : Kernels of groundnut cultivars (GPBD 4, TAG 24 and JL 24)

with a planting geometry of 30 cm × 15 cm. Whereas, cv. JL 24 recorded higher kernel yield (3185 kg ha^{-1}) at a plant density of 1,66,666 plants ha^{-1}.

4.3.7 Dry haulm yield (kg ha^{-1})

(c.f. Table 22)

Dry haulm yield differed significantly among the different groundnut cultivars. Dry haulm yield of cv. JL 24 was 1.49 and 6.55 per cent higher than cv. GPBD 4 (5556 kg) and cv. TAG 24 (5292 kg), respectively.

Influence of plant density on groundnut dry haulm yield was not-significant.

None of the interaction effects were found significant with respect to dry haulm yield.

4.3.8 Shelling percentage

(c.f. Table 23)

Shelling percentage did not differ significantly among the different groundnut cultivars. However, cv. GPBD 4 recorded higher shelling percentage (70.92) as compared to cv. TAG 24 (69.85) and cv. JL 24 (68.74).

Effect of plant density was significant with respect to shelling percentage. Higher shelling percentage (72.06%) was noticed at lower plant density (1,66,666 plants ha^{-1}) compared to medium and high plant density (2,22,222 and 3,33,333 plants ha^{-1}, respectively).

Interaction effect of cultivars and plant density failed to exert significant influence on shelling percentage.

4.3.9 100-kernel weight (g)

(c.f. Table 23)

Cultivars differed significantly with respect to 100-kernel weight. Higher 100-kernel weight was recorded in cv. JL 24 (43.78 g) compared to cv. GPBD 4 and cv. TAG 24 (36.24 and 42.61 g, respectively).

Effect of plant density was significant with respect to 100-kernel weight. Groundnut grown at a plant density of 1,66,666 plants ha^{-1} recorded higher 100-kernel weight (42.60 g) compared to medium and higher plant density (2,22,222 and 3,33,333 plants ha^{-1}).

Interaction effects of cultivars and plant density failed to exert significant influence on 100 kernel weight.

4.3.10 Percentage of sound mature kernels [SMK (%)]
(c.f. Table 23)

Sound mature kernels did not differ significantly among the different groundnut cultivars. However, higher percentage of SMK was observed in cv. GPBD 4 (82.02) over cv. TAG 24 and cv. JL 24 (79.14 and 77.53, respectively).

Plant density was failed to influence the percentage of sound mature kernels significantly.

Interaction effects of cultivars and plant density were not significant with respect to percentage of sound mature kernels.

4.3.11 Harvest index (HI)
(c.f. Table 23)

Cultivars differed significantly with respect to harvest index. Higher harvest index (0.521) was recorded in cv. TAG 24 compared to cv. GPBD 4 and cv. JL 24 (0.483 and 0.431, respectively).

Effect of plant density was significant with respect to HI. Medium plant density (2,22,222 plants ha^{-1} with a planting geometry of 30 cm × 15 cm) recorded higher HI (0.502) compared to other plant densities.

Cultivar TAG 24 produced higher HI (0.574) at a plant density of 2,22,222 plants ha^{-1} with a planting geometry of 30 cm × 15 cm compared to other plant densities. While, cv. GPBD 24 recorded higher harvest index (0.538) at a plant

Table 23 : Shelling percentage, 100-kernel weight (g), percentage of sound mature kernels and harvest index of groundnut cultivars as influenced by plant density

Plant density (plants ha^{-1})	Shelling percentage				100-kernel weight (g)				Percentage of sound mature kernels				Harvest index (HI)			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm × 10 cm)	69.73	70.04	67.55	**69.10**	34.00	41.63	41.97	**39.20**	81.09	77.72	75.93	**78.25**	0.500	0.544	0.429	**0.491**
2,22,222 (30 cm × 15 cm)	71.56	70.23	67.22	**69.67**	37.90	42.33	44.60	**41.61**	83.81	77.97	75.41	**79.06**	0.538	0.574	0.395	**0.502**
2,22,222 (45 cm × 10 cm)	66.47	67.77	68.80	**67.68**	35.10	42.33	42.87	**40.10**	77.37	79.52	79.06	**78.65**	0.388	0.455	0.445	**0.429**
1,66,666 (30 cm × 20 cm)	73.41	71.37	71.40	**72.06**	37.97	44.13	45.70	**42.60**	85.81	81.24	79.71	**82.25**	0.505	0.513	0.454	**0.491**
Mean	**70.92**	**69.85**	**68.74**	**69.63**	**36.24**	**42.61**	**43.78**	**40.88**	**82.02**	**79.14**	**77.53**	**79.55**	**0.483**	**0.521**	**0.431**	**0.478**
For comparing the two means of	S.Em±			LSD (0.05)	S.Em±			LSD (0.05)	S.Em±			LSD (0.05)	S.Em±			LSD (0.05)
Cultivars (cv.)	0.975			NS	0.604			2.37	1.696			NS	0.011			0.045
Plant density (PD)	0.825			2.45	0.402			1.20	1.483			NS	0.013			0.039
PD at the same cv.	1.430			NS	0.697			NS	2.569			NS	0.023			0.068
cv. at the same or different PD	1.576			NS	0.854			NS	2.797			NS	0.023			0.068

Note : NS – Non significant DAS – Days after sowing

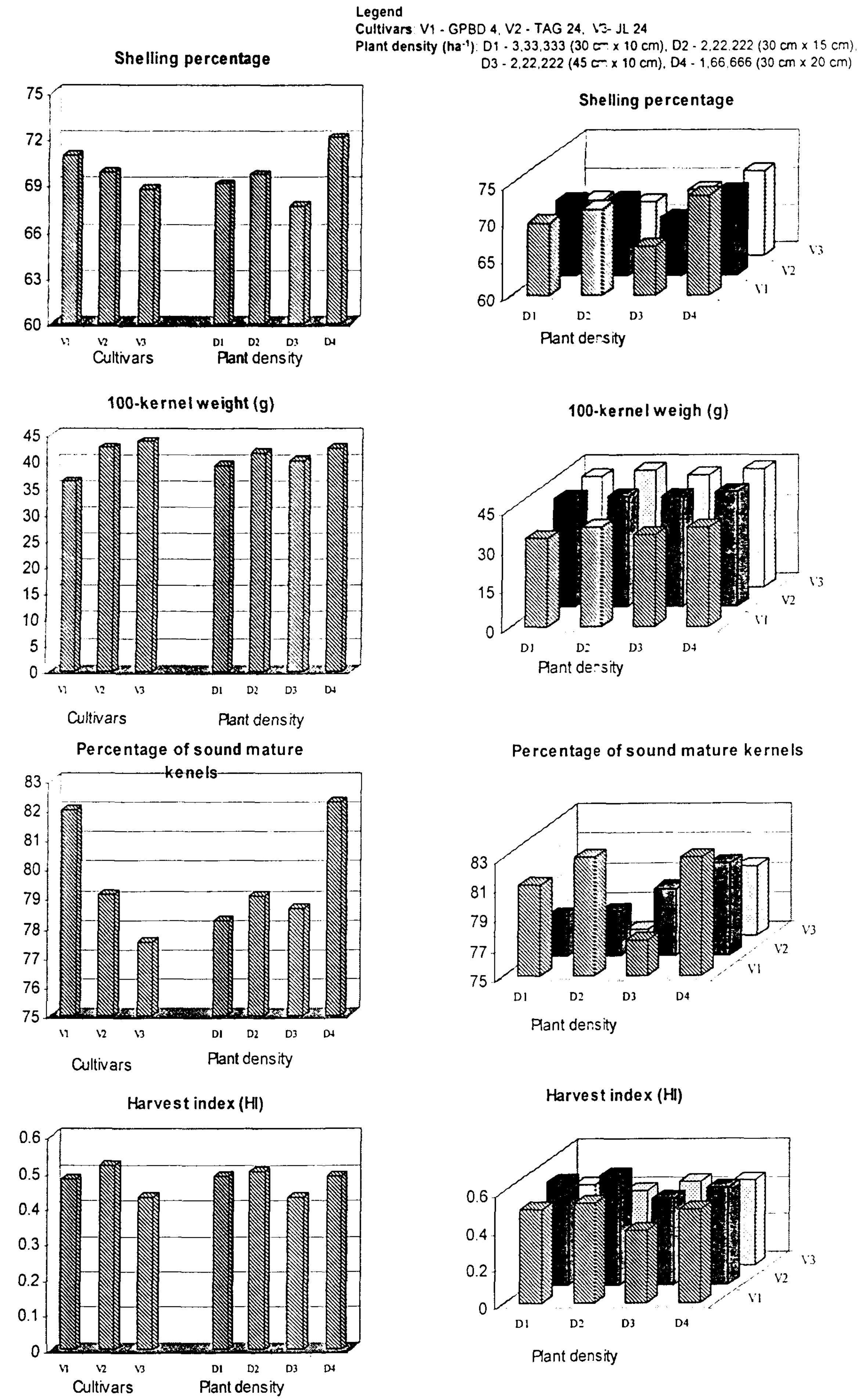


Fig. 8. Effect of plant density on shelling percentage, 100-kernel weight (g), percentage of sound mature kernels and harvest index (HI) of groundnut cultivars

density of 2,22,222 plants ha^{-1} (30 cm x 15 cm planting geometry). Whereas, cv. JL 24 maximized the harvest index (0.454) at a plant density of 1,66,666 plants ha^{-1}.

4.4 Quality

4.4.1 Oil content (%)

(c.f. Table 24)

Cultivars did not differ significantly with respect to oil content. However, cv. GPBD 4 recorded numerically higher kernel oil content (47.98%) as compared to cv. TAG 24 (47.23) and cv. JL 24 (47.94%).

Plant density failed to exert significant influence on oil content.

None of the interaction effects were found significant with respect to oil content.

4.4.2 Oil yield (kg ha^{-1})

(c.f. Table 24)

Cultivars showed significant difference in oil yield. Oil yield in cv. TAG 24 was 0.86 and 10.68 per cent higher over cv. GPBD 4 and cv. JL 24, respectively.

Effect of plant density was significant with respect to oil yield. Higher plant density (3,33,333 plants ha^{-1}) produced higher oil yield (1680 kg) compared to medium (1424 to 1562 kg ha^{-1}) and lower plant density (1563 kg ha^{-1}).

Cultivar TAG 24 maximized its oil yield (1857 kg) at a plant density of 3,33,333 plants ha^{-1}. While cv. GPBD 4 produced more oil yield (1799 kg) at a plant density of 2,22,222 plants ha^{-1} (30 cm × 15 cm planting geometry). Whereas, cv. JL 24 produced more oil yield (1532 kg) at a plant density of 1,66,666 plants ha^{-1}.

4.5 Correlation Analysis

(c.f. Table 25)

Dry pod yield (kg ha^{-1}) *was not correlated with morphological characters* except plant spread at harvest and number of nodules plant^{-1} at 60 DAS, growth parameters except leaf area plant^{-1}, yield and quality parameters.

Table 24 : Oil content (%) and oil yield (kg ha^{-1}) of groundnut cultivars as influenced by plant density

Plant density (plants ha^{-1})	Oil content (%)				Oil yield (kg ha^{-1})			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm × 10 cm)	47.85	48.12	48.29	**48.09**	1722	1857	1462	**1680**
2,22,222 (30 cm × 15 cm)	48.42	44.57	47.30	**46.77**	1799	1580	1308	**1562**
2,22,222 (45 cm × 10 cm)	48.05	47.88	48.08	**48.01**	1350	1438	1485	**1424**
1,66,666 (30 cm × 20 cm)	47.61	48.35	48.09	**48.01**	1553	1605	1532	**1563**
Mean	**47.98**	**47.23**	**47.94**	**47.72**	**1606**	**1620**	**1447**	**1558**
For comparing the two means of	S.Em±		LSD (0.05)		S.Em±		LSD (0.05)	
Cultivars (cv.)	0.537		NS		32.499		128	
Plant density (PD)	0.615		NS		44.414		132	
PD at the same **cv.**	1.065		NS		76.927		229	
cv. at the same or different **PD**	1.067		NS		74.125		220	

Note : NS – Non significant

Legend
Cultivars: V1 - GPBD 4, V2 - TAG 24, V3- JL 24
Plant density (ha^{-1}) D1 - 3,33,333 (30 cm x 10 cm), D2 - 2,22,222 (30 cm x 15 cm), D3 - 2,22,222 (45 cm x 10 cm), D4 - 1,66,666 (30 cm x 20 cm)

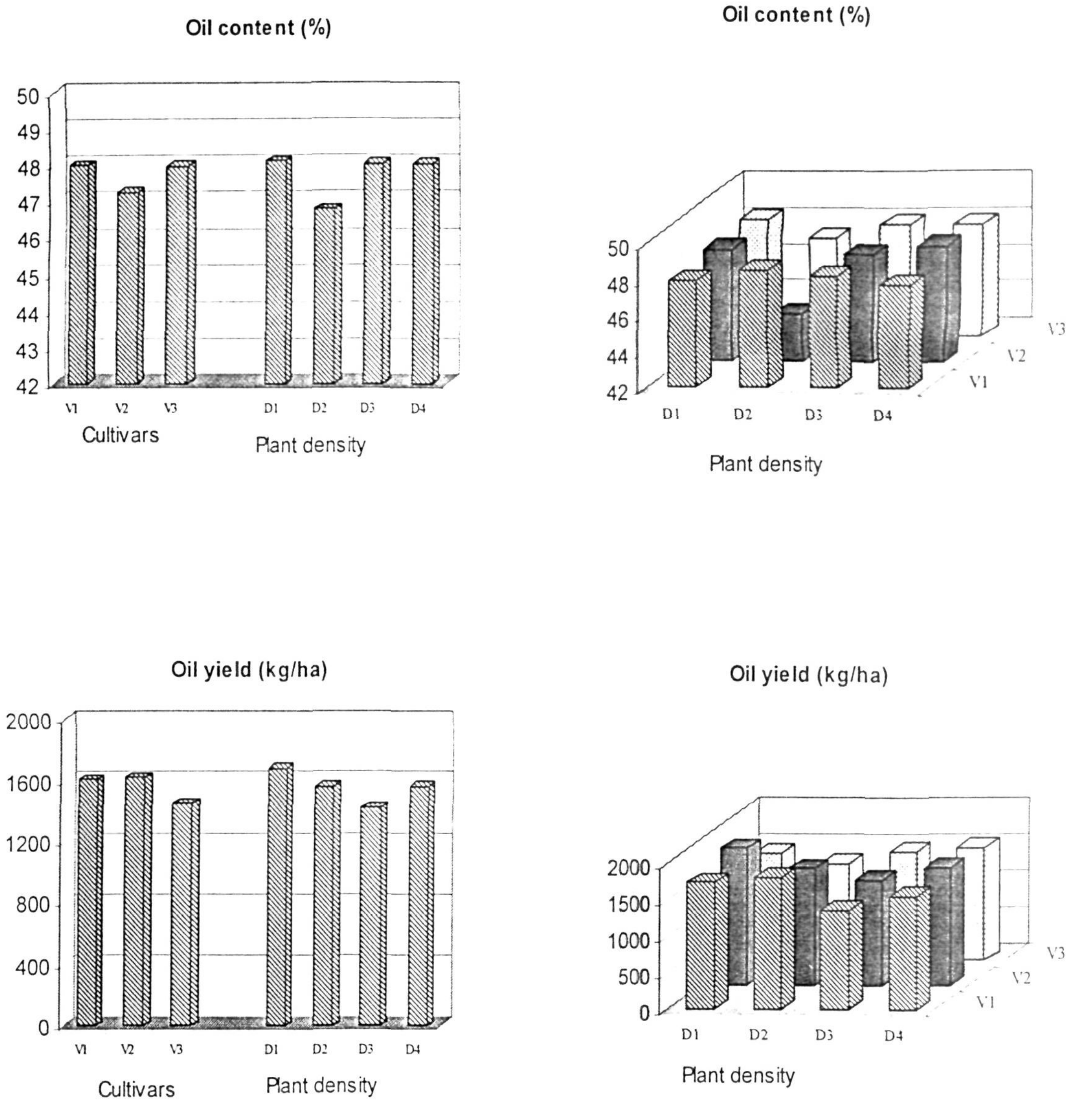


Fig. 9. Effect of plant density on oil content (%) and oil yield (kg/ha) of groundnut cultivars

Table 25 : Correlation coefficient ('r') between dry pod yield (kg ha^{-1}) and other parameters of groundnut cultivars as influenced by plant density

Sl.No	Parameters	'r' value
I.	**Morphological characters**	
	1. Plant height (cm) at harvest	-0.330
	2. Number of branches $plant^{-1}$ at harvest	-0.267
	3. Plant spread (cm) at harvest	-0.691*
	4. Number of nodules $plant^{-1}$ at 60 DAS	-0.590*
	5. Nodule dry weight (g $plant^{-1}$) at 60 DAS	-0.547
II.	**Growth parameters**	
	1. Total dry matter (g $plant^{-1}$) at harvest	-0.480
	2 Leaf area $plant^{-1}$ (dm^2) at harvest	-0.626*
	3. Leaf area index (LAI) at harvest	0.299
III.	**Yield components**	
	1. Number of developed pods $plant^{-1}$	-0.069
	2. Number of undeveloped pods $plant^{-1}$	0.273
	3. Total number of pods $plant^{-1}$	0.016
	4. Dry pod weight $plant^{-1}$ (g)	-0.381
	5. Shelling percentage	0.407
	6. 100-Kernel weight (g)	0.252
	7. Percentage of sound mature kernels	0.234
IV.	**Quality parameter**	
	1. Oil content (%)	-0.122

DAS – Days after sowing

* Significant at 5%

Table 26 : Gross returns (Rs. ha^{-1}), total cost of cultivation (Rs.ha^{-1}), net returns (Rs.ha^{-1}) and benefit : cost (B:C) ratio of groundnut cultivars as influenced by plant density

Plant density (plants ha^{-1})	Gross returns (Rs ha^{-1})				Total cost of cultivation (Rs ha^{-1})				Net returns (Rs ha^{-1})				Benefit cost (B:C) ratio			
	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean	GPBD 4	TAG 24	JL 24	Mean
3,33,333 (30 cm x 10 cm)	63899	68012	55666	**62525**	22218	22218	22218	**22218**	41681	45794	33448	**40308**	2.88	3.06	2.51	**2.81**
2,22,222 (30 cm x 15 cm)	64204	62393	51324	**59307**	19775	19775	19775	**19775**	44429	42618	31549	**39532**	3.25	3.15	2.60	**3.00**
2,22,222 (45 cm x 10 cm)	52672	54911	55812	**54465**	19775	19775	19775	**19775**	32897	35136	36037	**34690**	2.66	2.78	2.82	**2.75**
1,66,666 (30 cm x 20 cm)	55153	57588	55535	**56092**	18554	18554	18554	**18554**	36599	39034	36981	**37538**	2.97	3.10	2.99	**3.02**
Mean	**58982**	**60726**	**54584**	**58097**	**20080**	**20080**	**20080**	**20080**	**38901**	**40645**	**34503**	**38017**	**2.94**	**3.02**	**2.73**	**2.90**

For comparing the two means of	S.Em±	LSD (0.05)		S.Em±	LSD (0.05)	S.Em±	LSD (0.05)
Cultivars **(cv.)**	440.315	1729		440.779	1731	0.022	0.09
Plant density **(PD)**	787.666	2339		787.554	2339	0.039	0.12
PD at the same **cv.**	1364.277	4052		1364.083	4051	0.068	0.20
cv. at the same or different **PD**	1260.879	3745		1260.891	3745	0.063	0.19

4.6 Economic Analysis

(c.f. Table 26)

Gross returns, net returns and B:C ratio were significantly higher in cv. TAG 24 (Rs. 60,726 ha^{-1}, Rs.40,645 ha^{-1} and 3.02, respectively) compared to cv. GPBD 4 and cv. JL 24.

Groundnut grown at a plant density of 3,33,333 plants ha^{-1}, recorded higher gross returns, net returns (Rs.62,525 ha^{-1} and Rs.40,308 ha^{-1}, respectively). However, lower plant density (1,66,666 plants ha^{-1}) recorded higher B:C ratio (3.02).

Cultivar TAG 24 resulted in higher gross returns and net returns (Rs.68,012 ha^{-1} and Rs.45,794 ha^{-1}, respectively) at a plant density of 3,33,333 plants ha^{-1}, but B:C ratio was highest (3.15) at a plant density of 2,22,222 plants ha^{-1} (30 cm × 15 cm planting geometry). However, cv. GPBD 4 recorded higher gross returns, net returns and B:C ratio (Rs.64,204 ha^{-1}, Rs.44,429 ha^{-1} and 3.25, respectively) at a plant density of 2,22,222 plant ha^{-1} (30 cm × 15 cm planting geometry) Whereas, cv. JL 24 recorded higher gross returns (Rs.55,812 ha^{-1}) at 2,22,222 plants ha^{-1} (45 cm × 15 cm planting geometry) but net returns and B:C ratio were highest (Rs.36,981 ha^{-1} and 2.99, respectively) at a plant density of 1,66,666 plants ha^{-1}.

Discussion

V. DISCUSSION

Results of the field experiment on the "**Effect of plant density on growth and yield of groundnut cultivars under rainfed condition**" at Main Research Station, University of Agricultural Sciences, Dharwad, on medium black clayey soil during *kharif*, 2001 are discussed in this chapter.

Dharwad is situated at 15° 26′ N latitude and 75° 07′ E longitude in Northern Transitional Zone (Zone 8) of Karnataka. The rainfall received during 2001 (269.6 mm) was 65.64 per cent lower than average of 51 years rainfall (784.70 mm). The average dry pod yields obtained in the experiment were quite high as compared to the average yield of groundnut obtained by Patil *et al.* (1995). The higher average yields might be due to favourable climatic conditions prevailed during the experimental period (*Kharif*, 2001). The crop had received 152.8 mm rainfall in 17 rainy days during the crop growth period (7th July, 2001 to 11th October, 2001). Though, rainfall during the experimental year (2001) was low, but, the distribution was uniform throughout the crop growing period except 20th August to 16th September, during which one protective irrigation was given uniformly to a depth of 5 cm. Long and warm growing season coupled with abundance of sunshine and relatively warm temperature might be the reason for better average yields of groundnut during *kharif*, 2001.

5.1 Performance of groundnut cultivars

Many improved cultivars have been made available by introduction, selection, mutation and crossing. However, a superior cultivar in a particular locality may not exhibit its identical performance when it is grown under different set of agro-climatic conditions. It is, therefore, there is need to evaluate the high yielding groundnut cultivars suitable for different agro-climatic regions.

In the present investigation, among the cultivars, TAG 24 produced more dry pod yield and kernel yield (4908 and 3429 kg ha^{-1}, respectively) as compared to cv. GPBD 4 (4753 and 3347 kg ha^{-1}, respectively) and cv. JL 24 (4384 and 3016 kg ha^{-1}, respectively) (Table 22 and Fig.7).

Dry pod yield is governed by a number of factors, which have a direct or indirect impact. The main factors, which have direct bearing on dry pod yield are total number of pods $plant^{-1}$, number of developed pods $plant^{-1}$, shelling percentage, percentage of sound mature kernels and 100-kernel weight. The growth attributes like dry matter production $plant^{-1}$ and its distribution into various plant parts have an indirect influence on dry pod yield.

Among the yield components, dry pod weight $plant^{-1}$ was more closely associated with the dry pod yield ha^{-1}. Cultivar TAG 24 produced significantly higher dry pod weight $plant^{-1}$ (28.433 g) compared to cv. GPBD 4 (26.333 g) and cv. JL 24 (26.017 g) (Table 22 and Fig. 7). Such differences in cultivars with respect to dry pod weight $plant^{-1}$ have been reported earlier (Anonymous, 2000).

Similarly, total number of pods $plant^{-1}$ and number of developed pods $plant^{-1}$ were more in cv. TAG 24 (24.38 and 20.75, respectively) compared to national check cv. JL 24 (23.10 and 19.67, respectively) (Table 21 and Fig.6). Further, cv. TAG 24 showed higher shelling percentage (69.85) and higher percentage of sound mature kernels (79.14) as compared to cv. JL 24 (68.74 and 77.53, respectively) (Table 23 and Fig. 8). Such differences in cultivars with respect to yield components like total number of pods $plant^{-1}$, number of developed pods $plant^{-1}$, shelling percentage and percentage of sound mature kernels have been reported earlier (Agasimani *et al.*, 1984; Patil *et al.*, 1995; Anonymous, 1998; Patil and Nagaraja, 1999; and Anonymous, 2000).

Thus, owing to the integration of all the favourable yield components such as total number of pods $plant^{-1}$, number of developed pods $plant^{-1}$, shelling percentage and percentage of sound mature kernels in cv. TAG 24 resulted in significantly higher dry pod yield (kg ha^{-1}) over cv. JL 24. Positive and non significant correlation was observed between shelling percentage, percentage of sound mature kernels and dry pod yield ha^{-1}.

Eventhough, cv. GPDB 4 found superior with respect to total number of pods $plant^{-1}$, number of developed pods $plant^{-1}$, shelling percentage and percentage of sound mature kernels but due to more number of undeveloped pods $plant^{-1}$, lower dry pod weight $plant^{-1}$ and lower 100-kernel weight, it failed to produce more dry pod yield (kg ha^{-1}) over cv. TAG 24.

Differences observed in dry pod yield ha^{-1} and yield components can be traced back to the differences in dry matter production and its accumulation in different plant parts. Cultivar JL 24 produced significantly higher total dry matter $plant^{-1}$ at early crop growth stages (30 and 60 DAS) (Table 14 and Fig. 4a) compared to cv. GPBD 4 and cv. TAG 24. However, it did not show similar trend with respect to total dry matter $plant^{-1}$ at later growth stages (90 DAS and at harvest). At 90 DAS and harvest, total dry matter production $plant^{-1}$ was more in cv. TAG 24 (49.125 and 50.003 g, respectively) as compared to cv GPBD 4 (45.883 and 47.125 g, respectively) and cv. JL 24 (47.600 and 48.958, respectively) (Table 14 and Fig. 4a) . Such differences in cultivars with respect to total dry matter production $plant^{-1}$ have been reported by earlier workers (Gawasane *et al.*, 1988; and Sanjeev kumar and Aravind Kumar, 1999).

The total dry matter production $plant^{-1}$ alone does not reflect on the efficiency of a particular cultivar, but its distribution in different plant parts is the real index of the efficiency. According to Watson (1952), the rate of dry matter accumulation in the reproductive parts especially in pods would indicate the efficiency of cultivars. When the partitioning of total dry matter in different plant parts is examined (Table 18 and Fig.4a), it is apparent that cv. TAG 24 distributed higher proportion of dry matter in reproductive parts (56.60%) compared to cv. GPBD 4 (55.69%) and cv. JL 24 (53.03%). Therefore, cv. TAG 24 despite producing significantly lower total dry matter plant^{-1} than cv. JL 24 at early crop growth stages (30 and 60 DAS), produced higher dry pod yield due to greater proportion of dry matter in reproductive parts. Harvest index is another useful parameter to assess the translocation efficiency. Dry pod yield is related to biological yield through harvest index (HI) (Yoshida, 1972). Wallace and Munger (1966) opined that the total dry matter production was not sole determinant of plant yield, but harvest indices of cultivars determine the efficiency of dry matter utilization. In the present investigation, cv. TAG 24 recorded higher harvest index (0.521) than cv. GPBD 4 (0.483) and cv. JL 24 (0.431), which implies greater accumulation of dry matter in reproductive parts (Table 23 and Fig.8). Similar observations were also made by Deshmukh *et al.* (1993) and Patil *et al.* (1995), who reported cv. TAG 24 had higher harvest index compared to cv. JL 24, respectively.

Further, the dry matter accumulation in leaf and stem at all the growth stages was higher in cv. JL 24 than that of cv. GPBD 4 and cv. TAG 24 (Table 11 and Fig. 4a). At harvest, dry matter of vegetative parts (leaf and stem) accounted for 44.04 and 43.37 per cent in cv. GPBD 4 and cv. TAG 24, respectively, whereas, it was 46.66 per cent in cv. JL 24. This can be possibly attributed to tall and bushy nature of cv. JL 24. Cultivar JL 24 recorded significantly higher plant height at all the growth stages except at 30 DAS (Table 7). Plant spread and number of nodules plant^{-1} were higher in cv. JL 24 at all the growth stages over cv. GPBD 4 and cv. TAG 24 (Table 9 and 10).

Therefore, dwarf and compact nature of cv. TAG 24 might have allowed substantially less dry matter accumulation in leaf and stem compared to cv. JL 24. Klimove (1975) reported that optimum structure of dwarf cultivar could maximize productivity due to better photosynthetic to non-photosynthetic plant parts. Thus, dwarf and compact nature seems to be one of the ideal character for realizing higher dry pod yield.

Differences in dry matter production and its distribution in different plant parts arose because of various physiological factors during crop growth. Cultivar JL 24 recorded significantly higher leaf area and leaf area index (LAI) at all the crop growth stages compared to cv. GPBD 4 and cv. TAG 24. At harvest, cv. JL 24 recorded higher leaf area plant^{-1} and higher LAI (14.65 dm^2 and 3.436, respectively) compared to cv. GPBD 4 (12.42 dm^2 and 2.919, respectively) and cv. TAG 24 (13.24 dm^2 and 3.090, respectively) (Table 20). Yoshida (1972) opined that, higher LAI results in higher dry matter production but this relationship does not hold indefinitely because of mutual shading of the leaves resulting in reduced mean photosynthetic rate per unit area. When plant appearance is considered, cv. JL 24 was tall, bushy with larger leaves and more plant spread ; while, cv. TAG 24 was dwarf, compact with smaller leaves and less plant spread. The larger leaf area plant^{-1} in cv. JL 24 at 60 and 90 DAS (14.28 and 16.30 dm^2, respectively) compared to cv. GPBD 4 (12.04 and 14.21 dm^2, respectively) and cv. TAG 24 (13.01 and 15.18 dm^2, respectively) seems to have caused the shading of lower leaves, this might have reduced the photosynthetic activity (Table 19). This inturn might have reduced the assimilation of photosynthates in sink (reproductive parts). Although cv. JL 24 had higher leaf area and higher LAI at all the growth stages, but because of greater distribution of dry matter in vegetative parts (leaf and stem) rather than in reproductive parts especially in pods must have resulted in lower dry pod yield.

With respect to morphological parameters (number of branches plant^{-1}, plant spread and number of nodules plant^{-1}) and growth parameters (total dry matter production plant^{-1}, leaf area plant^{-1} and leaf area index) cv. GPBD 4 performed inferior to cv. TAG 24. This might be the reason for lower dry pod yield ha^{-1} in cv. GPBD 4 as compared to cv. TAG 24.

Cultivar JL 24 produced higher dry haulm yield (5639 kg ha^{-1}) compared to cv. GPBD 4 (5556 kg ha^{-1}) and cv. TAG 24 (5292 kg ha^{-1}) (Table 22 and Fig. 7). This might be due to tall and bushy nature of cv. JL 24 coupled with more plant spread. Such differences in cultivars with respect to dry haulm yield was reported earlier (Anonymous, 2000).

In the present investigation, it was observed that oil content (%) did not differ among cultivars. Further, oil yield is related to kernel yield in addition to oil content. The higher kernel yield of cv. TAG 24 resulted in higher oil yield (1620 kg ha^{-1}) inspite of low oil content (47.23%) (Table 24 and Fig. 9). Such differences in cultivars with respect to oil yield was noticed earlier (Sanjeev kumar and Aravind kumar, 1999).

Further, synchronous flowering, pods clustered around the main crown region, less number of pops, ease to harvest and no loss of pods during harvest due to the surface poding in cv. TAG 24 might have resulted in realizing higher dry pod yield compared to cv. GPBD and cv. JL 24.

Thus, it may be concluded that despite less number of branches $plant^{-1}$, less plant spread, less number of nodules $plant^{-1}$, lower nodule dry weight $plant^{-1}$, less leaf area $plant^{-1}$ and lower leaf area index, cv. TAG 24 out yielded cv. JL 24 due to efficient utilization of dry matter for pod production along with more number of pods $plant^{-1}$, higher shelling percentage, higher percentage of sound mature kernels and high harvest index (HI).

5.2 Effect of plant density

Maximum yield for a particular cultivar and environment can be obtained at plant density where competition between the plants is minimal. This can be achieved with optimum plant density, 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 increased with increasing plant density. Hence, optimum plant density induces the plant to achieve its potential yield.

In the present investigation, dry pod yield of groundnut increased from 4517 to 5048 kg ha- with increasing plant density from 1,66,666 to 3,33,333 plants ha^{-1} (Table 22 and Fig.7). Trend observed in the present investigation confirms the results obtained by earlier workers (Donga *et al.*, 1990; Basak *et al.*, 1995; Patel and Patel, 1995; and Lukunchauan *et al.*, 1997a), where they observed increased dry pod yield of bunch groundnut with increasing plant density. Choudhary *et al.* (1997) opined that dry pod yield increases to a maximum value but declines as plant density increases beyond certain level. Similar trend was also noticed with respect to kernel yield. Kernel yield increased from 3256 to 3495 kg ha^{-1} with increasing plant density from 1,66,666 to 3,33,333 plants ha^{-1} (Table 22 and Fig.7). Singh and Ahuja (1985) also reported increased kernel yield due to increased plant density.

Dry pod yield and kernel yield were higher at higher plant density despite the fact that total number of pods $plant^{-1}$, number of developed pods $plant^{-1}$, dry pod weight $plant^{-1}$, shelling percentage and 100 kernel weight were higher at lower plant density.

Dry pod weight $plant^{-1}$ reduced by 27.71 per cent due to increased plant density from 1,66,666 to 3,33,333 plants ha^{-1} (Table 22 and Fig.7). These findings are in confirmity with the results obtained by earlier researchers (Reddy and Gajendra Giri, 1989; and Raghavaiah *et al.*, 1995) and they observed dry pod weight $plant^{-1}$ decreased asymptotically with increasing plant density. This clearly indicates that higher dry pod weight $plant^{-1}$ at lower plant density could not compensate for the loss of dry pod yield ha^{-1} and kernel yield ha^{-1} due to less number of plants per unit area. Hence, dry pod yield ha^{-1} mainly depends upon the plant density per unit area.

Differences in dry pod yield ha^{-1} among the plant densities arose largely because of differences in yield components such as total number of pods $plant^{-1}$, number of developed pods $plant^{-1}$, dry pod weight $plant^{-1}$, shelling percentage, percentage of sound mature kernels and 100-kernel weight (Table 21,22,23 and Fig.6, 7 and 8). All these yield components decreased with increasing plant density form 1,66,666 to 3,33,333 plants ha^{-1}. High dry pod weight $plant^{-1}$ (30.556 g) in lower plant density was due to more number pods $plant^{-1}$ (27.42), more number of developed pods $plant^{-1}$ (23.67) and less number of undeveloped pods $plant^{-1}$ (3.76) (Table 21 and Fig. 6). Sufficient space for development of individual plants as well as pods at lower plant density (1,66,666 plants ha^{-1}) might have contributed to more number of pods $plant^{-1}$. These results are in confirmity with results obtained by Reddy and Gajendra Giri (1989); Jadhao *et al.* (1992); Basak *et al.* (1995); Mishra *et al.* (1998); and Patel (1999), who reported increased total number of pods $plant^{-1}$ with decreasing plant density. Availability of sufficient growth resources such as light, moisture and nutrients to an individual plant at lower plant density leading to enhanced plant growth and development might have led to more number of developed pods $plant^{-1}$ (23.67), which ultimately increased the dry pod weight $plant^{-1}$.

Further, high shelling percentage (72.06) and more 100-kernel weight (42.60 g) at lower plant density (1,66,666 plants ha^{-1}) compared to higher plant density (3,33,333 plants ha^{-1}) also contributed to higher dry pod weight $plant^{-1}$, which inturn resulted in higher dry pod yield ha^{-1} (Table 23 and Fig. 8). These results are in confirmity with the findings of Gopalaswamy *et al.* (1979); and Kaul (1999), who observed higher 100-kernel weight and higher shelling percentage at lower plant density. This is mainly due to better availability of resources (moisture, nutrients and light) for the growth and development of pods at lower plant density. Further, higher plant density is known to produce early flowering and pod setting with the result that the pods are uniformly filled leading to higher dry yield (Yoyock, 1979).

In the present investigation, variation in plant density (1,66,666 to 3,33,333 plants ha^{-1}) failed to influence the number of undeveloped pods $plant^{-1}$ and percentage of sound mature kernels significantly. These results are in confirmity with the finding of Patil (1984); and Mozingo and Steele (1989), who observed change in plant density did not influence the number of undeveloped $plant^{-1}$ and percentage of sound mature kernels, respectively.

The differences in various yield components, which led to significant yield differences among the plant densities could be traced back to differences in dry matter production and its distribution in different plant parts. The total dry matter $plant^{-1}$ obtained with lower plant density was higher (53.233 g) compared to higher plant density (42.910 g) (Table 14 and Fig. 4b). Similar observations were also made earlier by Chandrashekhara Reddy (1976); Biradar (1982); Patil (1984); Singh and Ahuja (1985) ; and Kaul (1999).

Leaf and stem dry matter $plant^{-1}$ increased with decreasing plant density (3,33,333 to 1,66,666 plants ha^{-1}) at all the growth stages. At harvest, increase in plant density from 1,66,666 to 3,33,333 plants ha^{-1} decreased the leaf and stem dry matter $plant^{-1}$ from 9.600 to 8.833 g and 13.078 to 11.989 g, respectively (Table 11, 12 and Fig. 4b). The extent of reduction in leaf and stem dry matter $plant^{-1}$ due to increased plant density tended to increase as the growth advanced. Thus, the increased leaf dry matter $plant^{-1}$ at lower plant density, which is usually associated with the increased leaf area $plant^{-1}$. This might have led to increased accumulation of photosynthates and relatively better yield $plant^{-1}$ at lower plant density than at higher plant density.

Similarly, reproductive dry matter $plant^{-1}$ increased with decreasing plant density (Table 13 and Fig. 4b). At harvest, the extent of reduction in reproductive dry matter due to increasing plant density from 1,66,666 to 3,33,333 plants ha^{-1} was 27.71 per cent. As the growth advanced dry matter accumulation in reproductive parts tended to increase.

Thus, owing to higher dry matter production $plant^{-1}$, higher leaf area $plant^{-1}$ aided by more number of developed pods $plant^{-1}$, there was greater distribution of dry matter in reproductive parts especially in pods. This might have led to increased developed pods $plant^{-1}$, dry pod weight $plant^{-1}$, shelling percentage and 100-kernel weight at lower plant density compared to higher plant density.

Higher total dry matter production $plant^{-1}$ at lower plant density (1,66,666 plants ha^{-1}) was due to increased number of branches $plant^{-1}$ and more plant spread (Table 8 and 9). Similar results were reported earlier workers (Mishra *et al.*, 1998; and Deshmukh and Bhoi, 1999), where it was observed that increased plant density resulted in decreased number of branches $plant^{-1}$ and plant spread. This might be due to more space and less competition for resources between plants, whereas, plant height increased with increased plant density (Table 7). Shortage of space and competition for resources at higher plant density led to taller plants. Similar results were also reported by Agasimani *et al.* (1984); Mozingo *et al.* (1990); and Deshmukh and Bhoi (1999), who observed that higher plant density promoted taller plants.

Number of nodules $plant^{-1}$ and nodule dry weight (g $plant^{-1}$) decreased with increasing plant density from 1,66,666 to 3,33,333 plants ha^{-1} at 45 and 60 DAS (Table 10). This might have led to increased atmospheric nitrogen fixation by the plant at lower plant density, which inturn might have resulted in better availability of nitrogen throughout the plant growth and development. Similar results were also reported by Patra *et al.* (1999), who observed more number of nodules $plant^{-1}$ at lower plant density.

Leaf area index (LAI) largely determines the productivity of a crop stand. Higher LAI values can be achieved by increasing plant density (Yoshida, 1972). At harvest, increased plant density from 1,66,666 to 3,33,333 plants ha^{-1} increased the LAI from 2.322 to 4.273, respectively (Table 20). Similar observations were also made by Biradar (1982). Thus, increased LAI due to increased plant density was the main physiological cause for significantly higher dry pod yield ha^{-1} at higher plant density than at lower plant density.

Further, increased plant density from 1,66,666 to 3,33,333 plants ha^{-1} increased the dry haulm yield (5384 to 5564 kg ha^{-1}, respectively) (Table 22 and Fig. 7), which might be due taller plants at higher plant density. This also confirms the results reported by Deshmukh and Bhoi (1999); and Patel (1999), who observed increased dry haulm yield with increasing plant density.

In the present investigation, it was observed that oil content (%) did not differ among plant densities. However, oil content was higher at higher plant density due to reduced 100-kernel weight and kernel size. Further, oil yield is related to kernel yield in addition to oil content. Hence, higher kernel yield at higher plant density resulted in higher oil yield (1680 kg ha^{-1}) inspite of low oil content (Table 24 and Fig. 9). Increased oil yield at increased plant density was also reported by Salem *et al.* (1984).

At constant plant density (2,22,222 plants ha^{-1}), planting geometry of 30 cm x 15 cm produced higher dry pod yield and kernel yield (4782 and 3338 kg ha^{-1}, respectively) as compared to planting geometry of 45 cm x 10 cm (4379 and 2968 kg ha^{-1}, respectively) (Table 22 and Fig. 7). This was mainly attributed to the higher total number of pods plant^{-1}, higher dry pod weight plant^{-1}, higher shelling percentage, higher 100-kernel weight, higher percentage of sound mature kernels and higher harvest index (HI) at a planting geometry of 30 cm x 15 cm over 45 cm x 10 cm planting geometry (Table 23 and Fig. 8).

Although, individual plant performance was better at lower plant density, yield per unit area was substantially lower at higher plant density. Because, under field conditions the dry pod yield is a reflection of productivity per unit area and not the individual plant performance. Thus, it can be concluded that groundnut grown at a plant density of 3,33,333 plants ha^{-1} with a planting geometry of 30 cm x 10 cm produced higher dry pod yield (5048 kg ha^{-1}) over 2,22,222 plants ha^{-1} either with a planting geometry of 30 cm x 15 cm or with 45 cm x 10 cm (4782 and 4379 kg ha^{-1}, respectively) and 1,66,666 plants ha^{-1} with a planting geometry of 30 cm x 20 cm (4517 kg ha^{-1}).

5.3 Performance of groundnut cultivars at different plant density

Dry pod yield of cv. TAG 24 was significantly higher (5509 kg ha^{-1}) at a plant density of 3,33,333 plants ha^{-} with a planting geometry of 30 cm x 10 cm. Dry pod yield of cv. TAG 24 increased with increasing plant density from 1,66,666 to 3,33,333 plants ha^{-1} and it was ranged between 4649 to 5509 kg ha^{-1} (Table 22 and Fig. 7). However, cv. GPBD 4 showed significant response to increasing plant density upto 2,22,222 plants ha^{-1} with a planting geometry of 30 cm x 15 cm. This might be due to its growth habit, as cultivar showed erectness at early growth stage (18.50 cm plant spread at 30 DAS) but spreads laterally at later growth stages (29.08 and 35.23 cm plant spread at 60 and 90 DAS, respectively). Whereas, cultivar JL 24 exhibited plasticity to different plant density of 3,33,333 plants ha^{-1} with a planting geometry of 30 cm x 10 cm (4476 kg ha^{-1}), 2,22,222 plants ha^{-1} with a planting geometry of 45 cm x 10 cm (4489 kg ha^{-1}) and 1,66,666 plants ha^{-1} with a planting geometry of 30 cm x 20 cm (4461 kg ha^{-1}) (Table 22 and Fig.7).

Kernel yield of cv. TAG 24 was significantly higher (3861 kg ha^{-1}) at a plant density of 3,33,333 plants ha^{-1} with a planting geometry of 30 cm x 10 cm. Kernel yield of cv. TAG 24 increased with increasing plant density from 1,66,666 to 3,33,333 plants ha^{-1} and it was ranged between 3320 to 3681 kg ha^{-1}. However, cv. GPBD 4 showed significant response to increasing plant density upto 2,22,222 plants ha^{-1} with a planting geometry of 30 cm x 15 cm. Whereas, cultivar JL 24 did not show any response to change in plant density (Table 22 and Fig. 7). Such difference in cultivars to plant density was also noticed by earlier workers (Biradar, 1982; and Mishra *et al.*, 1998).

The differences in dry pod yield ha^{-1} of groundnut cultivars to varying plant densities with respect to dry pod yield may be related to the differential effect of varying plant densities on dry pod weight $plant^{-1}$. Lesser reduction in dry pod weight $plant^{-1}$ of cv. GPBD 4 (29.83%) and cv. JL 24 (22.27%) at higher plant density (3,33,333 plants ha^{-1}) compared to cv. TAG 24 (30.55%) might have resulted in lack of response of cv. GPBD 4 and cv. JL 24 to increasing plant density beyond 2,22,222 plants ha^{-1} either with a planting geometry of 30 cm x 15 cm or with 45 cm x 10 cm.

Further, harvest index (HI) is another useful parameter to assess the translocation efficiency of cultivars at varied plant density. Cultivar GPBD 4 and cv. TAG 24 recorded lower harvest index (0.388 and 0.455, respectively) at a plant density of 2,22,222 plants ha^{-1} with a planting geometry of 45 cm x 10 cm. This might be due to lower dry pod yield and higher dry haulm yield. However, cv. JL 24 recorded higher HI (0.454) at lower plant density of 1,66,666 plants ha^{-1} due to higher dry pod yield ha^{-1} and lower dry haulm yield ha^{-1}.

Thus, under rainfed conditions of *kharif* in Northern Transitional Zone (Zone 8) of Karnataka cultivation of cv. TAG 24 at a plant density of 3,33,333 plants ha^{-1} with a planting geometry of 30 cm x 10 cm found superior on account of higher dry pod yield (5509 kg ha^{-1}), higher kernel yield (3861 kg ha^{-1}) and higher oil yield (1857 kg ha^{-1}) compared to cv. GPBD 4 and cv. JL 24.

5.4 Economics

Economic analysis revealed that cultivation of groundnut by using cv. TAG 24 at a plant density of 3,33,333 plants ha^{-1} with a planting geometry of 30 cm x 10 cm found superior on account of higher gross returns (Rs.68,012 ha^{-1}) and high net returns (Rs.45,794 ha^{-1}) (Table 26). However, the same cultivar grown at a plant density of 2,22,222 plants ha^{-1} with a planting geometry of 30 cm x 15 cm resulted in higher B:C ratio (3.15) on account of higher dry pod yield ha^{-1} and reduced seed requirement for sowing. While, cv. GPBD 4 at a plant density of 2,22,222 plants ha^{-1} with a planting geometry of 30 cm x 15 cm recorded higher gross returns (Rs.64,204 ha^{-1}), high net returns (Rs.44,429 ha^{-1}) and high B:C ratio (3.25) due to higher dry pod yield ha^{-1} and 25-30 per cent lower seed requirement for sowing. Whereas, higher net returns (Rs.36,981 ha^{-1}) and high B:C ratio (2.99) was recorded in cv. JL 24 at a plant density of 1,66,666 plants ha^{-1} with a planting geometry of 30 cm x 20 cm on account of higher dry pod yield ha^{-1} and 50 per cent lower seed requirement for sowing.

Summary

VI. SUMMARY

Groundnut (*Arachis hypogaea* L.) is regarded as king of vegetable oilseed in India. It is mainly used for extraction of oil and its kernels are rich and cheap source of vegetable protein (26%). Kernels also contain vitamins A, B and some members of B_2 group and minerals like phosphorus, calcium and iron. Therefore, groundnut is almost a class by itself amongst low priced food products.

Evaluation of indigenous and exotic germplasm of different groundnut cultivars over several years of All India Co-ordinated Research Project on Groundnut (AICRP), International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) and University of Agricultural Sciences, Dharwad has led to the identification of groundnut cultivars with better yield potential and quality under different agro-climatic conditions. Recently University of Agricultural Sciences, Dharwad has identified new cultivars for rainy and post rainy/summer seasons. The preliminary studies conducted at Main Research Station, University of Agricultural Sciences, Dharwad indicated superiority of cv. GPBD 4 in rainy season and cv. TAG 24 in post rainy/summer season. The preliminary studies also indicated that groundnut respond to varying plant density and response may vary with cultivars.

A field experiment was therefore, conducted to study the performance of the newly identified cultivars at varied plant density in medium black clayey soil of Northern Transitional Zone (Zone 8) of Karnataka during *kharif*, 2001 under rainfed conditions at Main Research Station, University of Agricultural Sciences, Dharwad.

In the present investigation (i.e. "Effect of plant density on growth and yield of groundnut cultivars under rainfed condition"), three groundnut cultivars; GPBD 4, TAG 24 and JL 24 were tried at three plant densities

(3,33,333, 2,22,222 and 1,66,666 plants ha^{-1}). Two planting geometries (30 cm x 10 cm and 45 cm x 10 cm) were tried at a plant density of 2,22,222 plants ha^{-1}. The experiment was laid out in split plot design with three replications. The findings of this experiment are summarized below.

Cultivar TAG 24 produced significantly higher dry pod yield and kernel yield (4908 and 3429 kg ha^{-1}, respectively) compared to cv. GPBD 4 (4753 and 3347 kg ha^{-1}, respectively) and cv. JL 24 (4384 and 3016 kg ha^{-1}, respectively). The yield components such as total number of developed pods plant^{-1} and dry pod weight plant^{-1} were higher in cv. TAG 24 as compared to cv. JL 24. Similarly, shelling percentage, percentage of sound mature kernels and harvest index were greater in cv. TAG 24 (69.85, 79.14 and 0.521, respectively) compared to cv. JL 24 (68.74, 77.53 and 0.431, respectively). On the contrary, cv. GPBD 4 recorded more number of developed pods plant^{-1} (23.40), higher shelling percentage (70.92%) and higher percentage of sound mature kernels (82.02) compared to cv. TAG 24 and cv. JL 24.

Total dry matter production plant^{-1} was greater in cv. JL 24 at initial growth stages [30 and 60 days after sowing (DAS)], while, cv. TAG 24 produced higher total dry matter production plant^{-1} (TDMP) at later growth stages (90 DAS and at harvest). At harvest, cv. TAG 24 had 2.15 and 5.81 per cent higher TDMP than cv. JL 24 (48.958 g) and cv. GPBD 4 (47.125 g). Similarly, dry matter distribution in reproductive parts was higher in cv. TAG 24 (56.60%) compared to cv. JL 24 (53.03%) and cv. GPBD 4 (55.69%). Leaf area plant^{-1} and leaf area index (LAI) were higher in cv. JL 24 (14.65 dm^2 and 3.436, respectively) compared to cv. GPBD 4 (12.42 dm^2 and 2.919, respectively) and cv. TAG 24 (13.24 dm^2 and 3.090, respectively).

Morphological parameters like plant height, number of branches plant^{-1}, plant spread, number of nodules plant^{-1} and nodule dry weight (g plant^{-1}) were higher in cv. JL 24 as compared to cv. GPBD 4 and cv. TAG 24.

However, cv. GPBD 4 performed inferior to cv. TAG 24 with respect to morphological parameters except plant height (number of branches plant^{-1}, plant spread, number of nodules plant^{-1} and nodule dry weight plant^{-1}), growth parameters (total dry matter production and its distribution in different plant parts, leaf area plant^{-1} and leaf area index) and yield parameters (dry pod weight plant^{-1} and 100-kernel weight).

Cultivars failed to show significant difference with respect to oil content. However, cv. TAG 24 produced more oil yield ha^{-1} (1620 kg) as compared to cv. GPBD 4 (1606 kg) and cv. JL 24 (1447 kg). Cultivar JL 24 recorded significantly higher dry haulm yield ha^{-1} (5639 kg) as compared to cv. GPBD 4 (5556 kg) and cv. TAG 24 (5292 kg).

Dry pod and kernel yield of groundnut increased (4517 to 5048 kg ha^{-1}; and 3256 to 3495 kg ha^{-1}, respectively) with increase in plant density from 1,66,666 to 3,33,333 plants ha^{-1}, respectively. Performance of individual plants with respect to morphological parameters except plant height, growth and yield parameters were superior at lower plant density (1,66,666 plants ha^{-1}) compared to performance at higher plant density (3,33,333 plants ha^{-1}).

Total dry matter production and its distribution in different plant parts tended to increase as plant growth advanced. Total dry matter production plant^{-1} at harvest was reduced by 11.90 per cent due to increased plant density from 1,66,666 (48.705 g) to 3,33,333 plants ha^{-1} (42.910 g). Further, the dry matter distribution in different plant parts (leaf, stem and reproductive parts) was higher at lower plant density (1,66,666 plants ha^{-1}) compared to that of higher plant density (3,33,333 plants ha^{-1}).

Although, individual plant performance was better at lower plant density, the performance on unit area basis was better at higher plant density on account of higher leaf area index and more number of plants per unit area.

Groundnut grown at 3,33,333 plants ha^{-1} recorded marginally higher kernel oil content (48.08%). However, significantly higher oil yield (1680 kg ha^{-1}) was obtained at a plant density of 3,33,333 plants ha^{-1} over 2,22,222 and 1,66,666 plants ha^{-1}.

At a constant plant density of 2,22,222 plants ha^{-1}, planting geometry of 30 cm x 15 cm produced significantly higher dry pod yield, kernel yield and oil yield (4782, 3338 and 1562 kg ha^{-1}, respectively) as compared to planting geometry of 45 cm x 10 cm (4379, 3088 and 1424 kg ha^{-1}, respectively) on account of higher total number of pods plant^{-1}, more number of developed pods plant^{-1}, higher dry pod weight plant^{-1}, higher shelling percentage, higher 100-kernel weight, higher percentage of sound mature kernels.

Dry pod yield, kernel yield and oil yield of cv. TAG 24 was significantly higher (5509, 3861 and 1857 kg ha^{-1}, respectively) at a plant density of 3,33,333 plants ha^{-1} with a planting geometry of 30 cm x 10 cm. While, cv. GPBD 4 maximized its dry pod, kernel and oil yield (5191, 3716 and 1799 kg ha^{-1}, respectively) at a plant density of 2,22,222 plants ha^{-1} with a planting geometry of 30 cm x 15 cm. However, cv. JL 24 recorded higher dry pod yield (4489 kg ha^{-1}) at 2,22,222 plants ha^{-1} with a planting geometry of 45 cm x 10 cm; and higher kernel and higher oil yield (3185 and 1532 kg ha^{-1}, respectively) at 1,66,666 plants ha^{-1} with a planting geometry of 30 cm x 20 cm.

Cultivar TAG 24 recorded higher gross returns (Rs.68012 ha^{-1}) and net returns (Rs.45794 ha^{-1}) at a plant density of 3,33,333 plants ha^{-1} with a planting geometry of 30 cm x 10 cm. But cv. GPBD 4 recorded higher B:C ratio (3.25) at a plant density of 2,22,222 plants ha^{-1} with a planting geometry of 30 cm x 15 cm.

Results of practical utility

In the present day context where in farmers are looking forward to commercial farming rather than subsistence farming. Hence, suitable crop husbandry methods for successful cultivation of groundnut will be of great help to farmers. Based on the results obtained from the present investigation in Northern Transitional Zone (Zone 8) of Karnataka, cultivar TAG 24 at a plant density of 3,33,333 plants ha^{-1} with a planting geometry of 30 cm x 10 cm or cv. GPBD 4 at a plant density of 2,22,222 plants ha^{-1} with a planting geometry of 30 cm x 15 cm can be adopted for cultivation on account of higher dry pod yield (5509 and 5191 kg ha^{-1}, respectively), higher kernel yield (3861 and 3716 kg ha^{-1}, respectively) and higher oil yield (1857 and 1799 kg ha^{-1}, respectively).

Future line of work

1. In the present investigation, cv. TAG 24 performed better at high plant density due to its compact and dwarfness. Therefore, there is need to test the performance of cv. TAG 24 at higher plant density beyond 3,33,333 plant ha^{-1}.
2. Response of groundnut cultivars at different plant density may be modified with different nutrient management practices. Therefore, there is a need to study the response of a particular groundnut cultivar with different nutrient management practices.

References

VII. REFERENCES

AGASIMANI, C.A., BABALAD, H.B. AND CHENNAALVEERSWAMI, A.S., 1989, Response of groundnut crop to plant population. *Indian Journal of Agronomy*, **34** : 135-137.

AGASIMANI, C.A., PALLED, Y.B., NAIK, H.D. AND KULKARNI, G.K., 1984, Response of groundnut cultivars to different spacings. *Indian Journal of Agronomy*, **29** : 209-212.

ANONYMOUS, 1998, *Annual Progress Report for 1997-98*, All India Co-ordinated Research Project on Groundnut, NRCG, Jungadh, pp. A13-A14.

ANONYMOUS, 2001, *Agriculture Statistics at a glance*, Government of India, New Delhi, pp. 74-77.

ANONYMOUS, 2000, *Annual Progress Report for 1999-2000*, All India Co-ordinated Research Project on Groundnut, NRCG, Jungadh, pp. A35-A36.

A.O.A.C., 1975, Official methods of analysis. (12th Edition) Willain Storwetzled. Published by A.O.A.C., Washington, D.C. pp. 506-508.

AZU, J.N. AND TANNER, J.W., 1978, Effect of plant density on growth, yield and grade of Spanish peanuts. *Proceedings of American Peanut Research and Education Association Inc.*, **1** : 72.

BASAK, N.C., CHOWDHURY, M.K. AND MIA, F.U., 1995, Effect of spacing on the yield and economics of groundnut. *Legume Research*, **18** : 45-49.

BIRADAR, S.B., 1982, Performance of groundnut genotypes in relation to inter and intra row spacing on irrigated black soil. *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Bangalore.

CHANDRASHEKHARA REDDY, S., 1976, Agronomic investigations on irrigated groundnut (*Arachis hypogaea* L.) under black clay soils. *Ph.D. thesis*, University of Agricultural Sciences, Bangalore.

CHARNER, A. AND ASHIRI, A., 1974, Vegetative and reproductive development of virginia type of peanut varieties in different stand densities. *Crop Science*, **14** : 412-416.

CHOUDHARY, B., ZAHID, M., GHOSH, P. AND SAMUI, R.C., 1997, Effect of seed rate and row spacing on confectionery groundnut in West Bengal, India. *International Arachis Newsletter*, **17** : 71-73.

DESHMUKH, G.N. AND BHOI, P.G., 1999, Effect of plant densities and fertilizer levels on growth and yield of groundnut (TAG 24). *Journal of Maharashtra Agricultural Universities*, **24** : 298-299.

DESHMUKH, S.N., MHASHAKSHETRI, P.N. AND FULZELE, G.R., 1993, Study on harvest index and its correlation with yield in some released varieties of groundnut (*Arachis hypogaea* L.). *Punjabrao Krishi Vidyapeth Research Journal*, **17** : 235-236.

DHOPTE, A.M. AND RAMTEKE, S.D., 1994, Relative variation in dry matter partitioning of peanut genotypes under moisture stress conditions. *Annals of Plant Physiology*, **8** : 174-178.

DONALD, C.M., 1962, In search of yield. *Journal of Australian Institute of Agricultural Sciences*, **28** : 171-178.

DONGA, P.P., JETHWA, M.G., PATEL, J.C., TANK, D.H. AND SADARIA, S.G., 1990, Response of spreading groundnut to sowing dates, spacings and fertilizers. *Indian Journal of Agronomy*, **35** : 332-333.

DWIVEDI, R.N. AND GAUTAM, J.K.S., 1992, Response of phosphorus level and spacing on groundnut (*Arachis hypogaea*) under agro-climatic conditions of Arunachal Pradesh. *Indian Journal of Agronomy*, **37** : 481-483.

EL SEESY, M.A. AND ASHOUB, A.H., 1994, Productivity of groundnut (*Arachis hypogaea* L.) as affected by different population and nitrogen levels. *Annals of Agricultural Sciences*, Moshtohor, **32** : 1199-1222.

GAWASANE, M.M., JADHAV, B.B. AND BIRANI, S.P., 1988, Physiological basis of varietal differences in yield of bunch type of groundnut. *Journal of Maharashtra Agricultural Universities*, **13** : 288-291.

GHOSH, P.K., DEVIDAYAL, NAIK, P.R., VIRENDRA SINGH, DAYAL, D. AND SINGH, V., 1997, Effect of seed maturity class and plant geometry on growth and yield of rainfed groundnut. *International Arachis Newsletter*, **17** : 51-52.

GOLDIN, E. AND HARTZOOK, A., 1986, The effect of intra row spacing on the vegetative and reproductive development of virginia bunch improved. *Israel Journal of Agricultural Research*, **16** : 151-156.

GOMEZ, K.A. AND GOMEZ, A.A., 1984, *Statistical Procedures for Agricultural Research*, An International Rice Research Institute Book, A Wiley-Interscience, John-Wiley and Sons Inc., New York, USA.

GOPALASWAMY, N., ELANGOVAN, R. AND RAJAH, C., 1979, Agronomic and economic optimum plant densities for rainfed groundnut. *Indian Journal of Agricultural Sciences*, **49** : 17-21.

GOWDA, M.V.C., MOTAGI, B.N., NAIDU, G.K., DIDDIMANI, S.B. AND SHESHAGIRI, R., 2002, GPBD 4 : A spanish bunch groundnut genotype resistant to rust and late leaf spot. *International Arachis Newsletter*. **22** :29-32.

ISHAG, H.M., 1970, Growth and yield attributes of irrigated groundnuts (*Arachis hypogaea* L.) grown at different spacing in Sudan Gazira. *Journal of Agricultural Sciences* (Cambridge), **74** : 533-537.

JACKSON, M.L., 1967, *Soil Chemical Analysis*, Prentice Hall of India Pvt. Ltd., New Delhi.

JADHAO, P.N., BHALERAO, P.D., THORVE, P.V. AND FULZELE, G.R., 1992, Effect of spacing on the yield of groundnut varieties during summer. *Indian Journal of Agronomy*, **37** : 79-81.

JADHAV, G.S., SHINDE, P.A. AND SURYAWANSHI, M.M., 2000, Comparative performance of groundnut genotypes under varying row and plant spacing in post monsoon environment. *Journal of Oilseeds Research*, **17** : 70-76.

JAYARAMAIAH, R. AND THIMMEGOWDA, S., 1997, Influence of different production technology on growth and yield of groundnut genotypes. *Crop Research Hisar*, **14** : 369-375.

JOHN, C.M., 1942, Groundnut as human food. *Madras Agricultural Journal*, **30** : 335-343.

KAUL, J.N., 1999, Response of groundnut (*Arachis hypogaea* L.) genotypes to planting geometry under sub-tropical conditions. *Indian Journal of Agricultural Sciences*, **69** : 458-460.

KLIMOV, S.V., 1975, The effects of lighting on the weight ratio of organs in different sunflower cultivars. *Biological Abstract*, **59** : 64-65.

KOPPALKAR, B.G., 1988, Studies on row proportion and plant density in groundnut (*Arachis hypogaea* L.) and sunflower (*Helianthus annuus* L.) intercropping system during summer under irrigated condition. *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Dharwad.

KUMARI, T.S. AND SINGH, B.G., 1990, Analysis of dry matter production and yield potential in groundnut genotypes. *Journal of Maharashtra Agricultural Universities*, **15** : 310-313.

KUSHWAHA, J.S. AND MISHRA, D.R., 1978, Effect of spacing on yield of groundout. *Indian Journal of Agronomy*, **24** : 341-344.

KVIEN, C.S. AND BERGMARK, C.L., 1987, Growth and development of the florunner peanut cultivar as influenced by population, planting date and water availability. *Peanut Science*, **14** : 11-16.

LAURENCE, R.C.N., 1974, Population and spacing studies with Malawian groundnut cultivars. *Experimental Agriculture*, **18** : 177-184.

LIPSCOMB, R.W., ROBERTSON, W.K. AND CHAPMAN, W.H., 1964, The effect of spacing and fertility on yield and quality of Dixie Spanish and early runner peanuts grown on Ruston fine sandy loam. *Third National peanut Research Conference Proceedings*, p.61.

LUKUNCHAVAN, YEH MAUSHING, YANG KINSHING, LU HUNGSHUNG, LU, K.C., YEH, M.S., YANG, K.S. AND LU, H.S., 1997a, Effect of genotype, population density and harvest date on pod maturity of peanut. *Journal of Agricultural Research of China*, **46** : 132-141.

MAO, H.C. AND HSU, C.S., 1975, Study on sowing pattern for mechanical cultivation of groundnut. *Taiwan Agriculture Quarterly*, **11** : 115-120.

MARANI, A., HURWITZ, S., LACHOVER, D. AND GOLDIN, E., 1961, Growth and nutrient uptake of two varieties of groundnut under irrigation in Israel. *Qualitative Plant Material Vegetable*, **8** : 241-260.

MISHRA, C.M., 1998, Effect of fertilizer levels on groundnut under dryland conditions. *Madras Agricultural Journal*, **84** : 112-113.

MISHRA, R.K., CHAUDHARY, S.K., PANDEY, U.K. AND SHARMA, R.B., 1998, Effect of varieties and plant density on productivity of groundnut. *Journal of Oilseeds Research*, **15** : 180-181.

MOZINGO, R.W. AND COFFELT, T.A., 1980, Effects of cultivars, row patterns and plant population on the yield value and grade of virginia type peanuts. *Proceedings of American Peanut Research Education Society*, Inc., **12** : 76.

MOZINGO, R.W. AND STEELE, 1989, Intra row seed spacing effects on morphological characteristics, yield, grade and net value of five peanut cultivars. *Peanut Science*, **16** : 95-99.

MOZINGO, R.W., WRIGHT, F.S. AND POWELL, N.L., 1990, Research indicates better returns with improved management practices for peanuts. *Better Crops with Plant Food*, **74** : 14-16.

MUHR, G.R., DATTA, N.P. AND DOHANUE, R.L., 1965, *Soil Testing in India*, U.S.A.I.D., New Delhi.

NAGARAJ, M.V., 1999, Effect of plant density and fertilizer management practices on growth, yield and quality of confectionery groundnut. *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Dharwad.

NANDANIA, V.A., MODHAWADIA, M.M., PATEL, J.C., SADARIA, S.G. AND PATEL, B.S., 1992, Response of rainy-season bunch groundnut (*Arachis hypogaea* L.) to row spacing and seed rate. *Indian Journal of Agronomy*, **37** : 597-599.

PATEL, J.B. AND PATEL, I.S., 1995, Effect of irrigation, interrow spacing and seed rate on quality and economics of summer groundnut. *International Arachis Newsletter*, **15** : 85-86.

PATEL, J.R., 1999, Effect of spacing, nitrogen and phosphorus on summer groundnut. *Journal of Oilseeds Research*, **16** : 346-347.

PATEL, J.S., KISTARIA, M.N., PAIDA, V.P., PARMAR, M.T. AND PATEL, J.C., 1985, Response of rainfed groundnut to varying spacings. *Indian Journal of Agronomy*, **30** : 468-469.

PATIL, C. AND NAGARAJA, A., 1999, Studies on seed crop protection on field performance of groundnut cultivars. *Journal of Oilseeds Research*, **16** : 151-156.

PATIL, J.V., 1984, Effect of row spacing and plant population on growth and yield of rainfed spreading groundnut (*Arachis hypogaea* L.). *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Bangalore.

PATIL, S.H., KALE, D.M., DESHMUKH, S.N., FULLELE, G.R. AND WEGINWAR, B.G., 1995, Semi dwarf, early maturing and high yielding new groundnut variety. TAG 24. *Journal of Oilseeds Research*, **12** : 254-257.

PATRA, A.K., TRIPATHY, S.K. AND SAMUI, R.C., 1999, Effect of sowing date, irrigation and spacing on nodulation, dry matter and yield of summer groundnut. *Indian Journal of Agronomy*, **44** : 800-804.

PIPER, C.S., 1966, *Soil and Plant Analysis*, Hans Publication, Bombay, p. 236.

RAGHAVAIAH, C.V., PADMAVATHI, P. AND PRASAD, M.V., 1995, Response of groundnut genotypes to plant density and phosphorus nutrition in Alfisols. *Journal of Oilseeds Research*, **12** : 295-298.

REDDY, N.R.N. AND GAJENDRA GIRI., 1989, Response of groundnut varieties to plant density and phosphorus. *Indian Journal of Agronomy*, **34** : 515-516.

REDDY, P.R. AND REDDY, C.S., 1998, Effect of intra-row spacings on Spanish bunch groundnut varieties under rained conditions. *Journal of Oilseeds Research*, **15** : 135-137.

SALEM, M.S., SERRY, M. AND SOLIMAN, M.M., 1984, Plant density and yield relation in peanut (*Arachis hypogaea* L.). *Annals of Agricultural Sciences*, **29** : 203-212.

SANDHU, B.S. AND HUNDAL, S.S., 1993, Effect of row spacing and sowing time on production potential of groundnut. *Indian Journal of Agronomy*, **38** : 422-426.

SANJEEV KUMAR AND ARAVIND KUMAR, 1999, Dry matter partitioning in different plant parts of Spanish and Virginia groundnut cultivars in mid-western plains of Uttar Pradesh. *Journal of Oilseeds Research*, **16** : 354-357.

SARAH, 1973, *Annual Report for the year 1971*, Department of Agriculture, Kotakinabulu, Subah, Malaysia, Government Printer, p.115.

SATHONE, K.M. AND BABULKAR, P.S., 1991, Response of summer groundnut to phosphate fertilization in vertisol. *Journal of Maharashtra Agricultural Universities*, **16** : 113-114.

SESTAK, L., CATASKY, J. AND JARVIS, P.G., 1971, Plant photosynthetic production : Manual of Methods Ed. Junk, N.V., The Hague Publishers.

SINGH, K.P. AND AHUJA, K.N., 1985, Dry matter accumulation, oil content and nutrient uptake in groundnut (*Arachis hypogaea* L.) CV. J-64 as affected by fertilizers and plant density. *Indian Journal of Agronomy*, **30** : 40-45.

SUBBIAH, B.Y. AND ASIJA, G.L., 1956, A rapid procedure for estimation of available nitrogen in soils. *Current Science*, **25** : 259-260.

SURAJ BHAN AND MISHRA, D.K., 1971, Studies on optimum spacing and manurial requirements of groundnut (*Arachis hypogaea* L.) in western Rajastan. *Indian Journal of Agronomy*, **16** : 310-312.

TARIMO, A.J.P. AND BLAMEY, F.P., 1999, Effect of plant population density and cultivar on growth, yield and yield components in groundnut (*Arachis hypogaea* L.). *South African Journal of Plant and Soil*, **16** : 74-78.

VIVEKANANDAN, A.S., GUNASENA, H.P.M. AND SIVANAYAGAM, T., 1972, Statistical evaluation of the techniques used in the estimation of leaf area in crop plants. *Indian Journal of Agricultural Sciences*, **42** : 857-860.

WALLACE, D.H. AND MUNGER, H.M., 1966, Studies on the physiological basis for yield differences : II. Variation in dry matter distribution among aerial organ for several dry bean varieties. *Crop Science*, **6** : 503-507.

WATSON, D.J., 1952, The physiological basis of variation in yield. *Advances in Agronomy*, **4** : 101-145.

WOODROOF, J.C., 1973, Peanuts-production, Processing Products. *Avi. Pub. Co. Inc*, Connecticut (USA).

YARGATTIKAR, R.J., 1986, The influence of plant population and row proportion of groundnut (*Arachis hypogaea* L.) and sunflower (*Helianthus annuus* L.) on oil production potential under intercropping system. *M.Sc.(Agri.) Thesis*, University of Agricultural Sciences, Dharwad.

YOSHIDA, S., 1972, Physiological aspects of grain yield. *Annual Review of Plant Physiology*, **23** : 437-464.

YOYOCK, J.Y., 1979, Effect of population density and fertilizer level on the economic yield of five varieties of groundnut at three locations in Nigeria. *Indian Journal of Agricultural Sciences*, **11** : 867-874.

Appendix

Appendix I : Price of inputs and outputs used in calculating cost and returns

	Item	Unit	Price (Rs.)
A.	**Inputs**		
	Seeds	Kg	52.50
	Fertilizer		
	Diammonium phosphate (DAP)	Kg	8.95
	Muriate of potash (MOP)	Kg	4.35
	Rhizobium	kg	50.00
	Captan	kg	1500.00
	Pendimethalin (30% EC)	l	480.00
	Monocrotophos (36 SL)	l	290.00
	Lambda-cyhalothrin (0.05 EC)	l	600.00
	Mancozeb (75% WP)	kg	210.00
	Carbendizim (50% WP)	kg	460
	Labour		
	Male	Day	35.00
	Female	Day	35.00
	Bullock pair	Day	180.00
B.	**Output**		
	Pods	kg	12.00
	Haulm	t	350.00

EFFECT OF PLANT DENSITY ON GROWTH AND YIELD OF CULTIVARS UNDER RAINFED CONDITION

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ABSTRACT

Field experiment to study the "Effect of plant density on growth and yield of groundnut cultivars under rainfed condition" was conducted at Main Research Station, University of Agricultural Sciences, Dharwad on medium black clayey soil (pH – 7.9, organic carbon – 0.72%, Available N – 308 kg ha^{-1}, Available P_2O_5 - 45.80 kg ha^{-1} and Available K_2O - 408 kg ha^{-1}) during *kharif*, 2001.

In the present investigation, three groundnut cultivars; GPBD 4, TAG 24 and JL 24 were tried at three plant densities (3,33,333, 2,22,222 and 1,66,666 plants ha^{-1}). Two planting geometries (30 cm x 10 cm and 45 cm x 10 cm) were tried at a plant density of 2,22,222 plants ha^{-1}. The experiment was laid out in Split Plot Design with three replications. Since the crop undergone severe moisture stress during its growth period (between 45 and 70 days after sowing), one protective irrigation was given uniformly to a depth of 5 cm.

Cultivar TAG 24 produced significantly higher dry pod and kernel yield (4908 and 3429 kg ha^{-1}, respectively) as compared to cv. GPBD 4 (4753 and 3347 kg ha^{-1}, respectively) and cv. JL 24 (4384 and 3016 kg ha^{-1}, respectively). The yield components such as total number of developed pods $plant^{-1}$, dry pod weight $plant^{-1}$, shelling percentage, percentage of sound mature kernels and harvest index were greater in cv. TAG 24. Cultivar TAG 24 produced high total dry matter $plant^{-1}$ as compared to cv. GPBD 4 and JL 24. Further, cv. TAG 24 accumulated greater dry matter in reproductive parts (56.60%) as compared to cv. JL 24 (53.03%) and cv. GPBD 4 (55.69%).

Dry pod yield of groundnut increased from 4517 to 5048 kg ha^{-1} and kernel yield from 3256 to 3495 kg ha^{-1} with increase in plant density from 1,66,666 to 3,33,333 plants ha^{-1}, respectively. The performance of individual plants with respect to morphological parameters except plant height; growth and yield parameters were superior at lower plant density (1,66,666 plants ha^{-1}) as compared to performance at higher plant density (3,33,333 plants ha^{-1}).

Dry pod, kernel and oil yields of cv. TAG 24 were significantly higher (5509, 3861 and 1857 kg ha^{-1}, respectively) at a plant density of 3,33,333 plants ha^{-1} with a planting geometry of 30 cm x 10 cm. While, cv. GPBD 4 maximized its dry pod, kernel and oil yields (5191, 3716 and 1799 kg ha^{-1}, respectively) at a plant density of 2,22,222 plants ha^{-1} with a planting geometry of 30 cm x 15 cm. However, cv. JL 24 recorded higher dry pod yield (4489 kg ha^{-1}) at 2,22,222 plants ha^{-1} with a planting geometry of 45 cm x 10 cm; and higher kernel and oil yields (3185 and 1532 kg ha^{-1}, respectively) at 1,66,666 plants ha^{-1} with a planting geometry of 30 cm x 20 cm.