AGRISTOMETIC MANAGEMENT TECHNOLOGIES FOR PEANUT PRODUCTION: A REVIEW

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ABSTRACT

Major reasons for low peanut yield in India are the use of low yield potential varieties, maintenance of inadequate plant population, poor soil fertility and water management. Peanut perform better in terms of yield and quality when good cultivar sown under optimum plant density coupled with efficient nutrient and water management. Several studies indicated that proper crop geometry facilitates sufficient interception of sunlight and satisfactory absorption of nutrients and water from the soil due to proper development of root system. Groundnut being a leguminous crop, it is capable of fixing atmospheric nitrogen by the root nodule bacteria. Application of nitrogenous fertilizer at lower doses would be sufficient and also, application of phosphorus and potassium in adequate quantities become more essential for obtaining higher yields. Several workers have shown that adoption of an improved variety alone can increase the yield by about 20 per cent. There are reports that application of gypsum to peanut increased the seedling vigour, seed yield and quality by altering the soil physical characteristics.

Key words: Agronomic management, Peanut production.

The peanut, or peanut (Arachis hypogaea), is a species in the legume family (Fabaceae) native to South America, Mexico and Central America. It is an annual herbaceous plant growing to 30 to 50 cm (1 to 1.5 ft) tall. The leaves are opposite, pinnate with four leaflets (two opposite pairs; no terminal leaflet), each leaflet 1 to 7 cm (⅛ to 2¾ inch) long and 1 to 3 cm (⅛ to 1 inch) broad. The flowers are a typical pea flower in shape, 2 to 4 cm (¾ to 1½ inch) across, yellow with reddish veining. After pollination, the fruit develops into a legume 3 to 7 cm (1 to 2 inch) long, containing 1 to 4 seeds, which forces its way underground to mature. Peanuts are also known as earthnuts, ground nuts, goobers, goober peas, pindas, jack nuts, pinders, manila nuts, g-nuts, and monkey nuts; the last of these is often used to mean the entire pod. Thousands of peanut cultivars are grown, with four major Cultivar Groups being the most popular: Spanish, Runner, Virginia, and Valencia. There are also Tennessee Red and Tennessee White groups. Certain Cultivar Groups are preferred for particular uses because of differences in flavor, oil content, size, shape, and disease resistance. For many uses the different cultivars are interchangeable. Most peanuts marketed in the shell are of the Virginia type, along with some Valencias selected for large size and the attractive appearance of the shell. Spanish peanuts are used mostly for peanut candy, salted nuts, and peanut butter. Most Runners are used to make peanut butter. The various types are distinguished by branching habit and branch length. There are numerous varieties of each type of peanut. There are two main growth

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forms, bunch and runner. Bunch types grow upright, while runner types grow near the ground.

China leads in production of peanuts having a share of about 37.5% of overall world production, followed by India (roughly 19%) and Nigeria (roughly 11%).

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<th>Country</th>
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<td>India</td>
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The ability of a genotype for a positive response to higher level of nutrients depends upon season and other bio and physico environments, which evidently have a significant functional relationship. In respect of different peanut genotypes, plant density and its nutrient management play a pivotal role in influencing the pod yield.

1. Influence of season: Groundnut is cultivated commercially in both Kharif as well as Rabi/summer seasons. In kharif (rainy) season the crop is grown under rainfed conditions between May to December by planting varieties belonging to different habit groups. In contrast, during Rabi/Summer (post rainy) season the varieties belonging to pish bunch and valencia are preferred for their shorter duration and are grown under irrigated conditions. Patra et. al. (1995) studied the seasonal effect on growth and yield of peanut variety JL 24 at Kalyani, West Bengal and reported higher plant height, dry matter production, LAI, CGR, LAD, hundred kernel weight, number of kernels pod⁻¹, pod and haulm yield during summer season compared to rainy season. However, the number of pods plant⁻¹ was higher in rainy season than in summer season. Liang Xuanquiang et.al. (1996) assessed the performance of fifteen peanut genotypes developed at ICRISAT in rainfed upland fields during autumn and spring seasons. During both the seasons, the large seeded peanut variety ICGV 86742 gave significantly higher pod yield of 2.35 t ha⁻¹ indicating no seasonal variation. Similar observation was also made by Patra et.al. (1996) in ICGS 44 variety, which performed well in terms of pod and oil yields during both rainy and summer seasons. Further, Tirupati 4, a Spanish bunch variety was compared with JL 24 during three kharif and three Rabi seasons, and found that pod and kernel yield of Tirupati 4 was 19 and 20 per cent more in the Kharif season, and 16 and 24 per cent more in the Rabi season, respectively than JL 24 which indicated the stability of the variety (Ramachandra Reddy et.al. 2000). Subramaniyam et.al. (2000) on identification of elite short duration rosette lines in world germ plasm collection revealed that among the fifteen peanut genotypes studied during rainy and post rainy seasons, irrespective of the peanut genotypes, the higher pod yield was observed during rainy season as compared to post rainy season.

2. Influence of cultivars: India is facing shortage of edible oils at present due to which we have to resort to large scale imports at the expense of huge foreign exchange. One of the main reasons for the low yield of production in the country is the wide scale non-adoption of newer varieties. It is a well established fact that adoption of an improved variety alone can increase the yield by about 20 per cent. In India over 60 improved groundnut varieties...
have been released by our scientists for general cultivation. Non-availability of suitable varieties for specific situation is one of the major causes for low productivity of peanut in India.

The cultivated groundnut (Archis hypogaea Linn.) has three distinct botanical groups viz., pish (Sub sp. Fastigiata var. vulgaris), Valencia (Sub sp. Fastigiata var. Fastigiata) and Virginia (Sub sp. Hypogaea var. hypogaea). The pish and valencia types popularly called as “Bunch” grow erect, possess light green foliage and produce pods in clusted at the base of the plant. The seeds are non-dormant and roundish with light rose testa (deep rose or purple testa in valencia). The virginia group which includes both virginia bunch (Semi-spreading) and virginia runner (spreading) types, on the other hand, possesses dark green foliage and the branches trail on the soil surface either partially or completely. The main stem is devoid of fruit and pods and are scattered all along the branches. The seeds are dormant, oblong in shape with brownish testa. In general, the spreading and semi-spreading varieties mature late as compared with the bunch varieties.

2.1. Growth characters: Bhale Rao et al. (1993) studied the growth performance of different peanut genotypes viz., J 19, Sel. 7-9-5, ICGV 86309 and ICGV 87189 during summer season and the highest plant height was observed with J 19 compared to other genotypes. At Dharwad, Karnataka, fifteen early-maturing peanut varieties were evaluated and the results showed that height and days to 50 per cent flowering varied significantly among the varieties. The varieties TMV 2 and KRG 1 recorded significantly higher plant height of 28.3 and 28.7 cm respectively and both the varieties came earlier to 50 per cent flowering on 30 DAS compared to the rest of the varieties (Amaregouda and Kamannavar, 1996). Mohiuddin and Ghosh (1996) conducted studies with ten peanut varieties at Sriniketan, West Bengal and the results revealed that plant height and number of branches plant\(^{-1}\) differed greatly among the varieties. The varieties SPS 38, B 31, JL 24 and ICGS 44 were taller with more number of branches plant\(^{-1}\) than other varieties. Peanut genotypes evaluated by Raja Rajeswari (1999) showed that the genotypes K 1128 and K 153 gave significantly higher plant height, leaf dry mass and stem dry mass as compared to TMV 2, JL 24 and Kadiri 3. Significant variation in root length and total dry matter production was observed among the genotypes studied at Tirupati. Among the varieties studied, ICGV 86031 and TMV 2 had the highest total dry matter production under moisture stress situation compared to ICG 476 (Reddy et al. 1999). Edna Antony et al. (2000) reported that maximum LAD was recorded with Spanish bunch variety Mardur local and Virginia type ICGS 76 while the higher value of LAI was observed in JL 24 and ICGS 76 peanut varieties. The NAR was maximum with the genotypes belonging to Spanish bunch (S 206 and JL 24) at early stage of crop growth. Nautiyal et al. (2002) compared different peanut genotypes in the soils of Mundra in Gujarat and found that TKG 19 A and ICGS 76 recorded significantly higher number of pegs plant\(^{-1}\), total dry matter production and harvest index than that of Kadiri 3 and ICG 3793 peanut varieties.

2.2. Yield and yield attributes: Four peanut genotypes were evaluated at Akola during summer season and the results revealed that the genotypes Sel 7-9-5 gave significantly higher pod yield of 2163 kg ha\(^{-1}\) compared to ICGV 86309 (2101) kg ha\(^{-1}\) and J 19 (1858 kg ha\(^{-1}\)). The higher pod yield recorded under Sel 7-9-5 was due to higher values of yield attributing characters viz., number of pods plant\(^{-1}\), weight of pods plant\(^{-1}\) and 100 pod weight (Bhale Rao et al. 1993). Rahman et al.
(1995) evaluated the performance of Birsa Bold 1, a promising confectionery peanut variety with M 13 during Kharif season and observed the superior performance of Birsa Bold 1 in respect of seed yield, 100 seed mass and high proportion of sound matured seeds. Research conducted at West Bengal indicated that cultivar TG 23 recorded significantly higher pod yield of 2.21 t ha\(^{-1}\) and shelling percentage of 70 as compared to ICGS 5 and ICGS 11 peanut varieties during post rainy / summer seasons (Samui and Minajur Ahesan, 1995).

Amaregouda and Kamannavar (1996) compared the performance of six early maturing peanut varieties and found that pod yield (2.63 t ha\(^{-1}\)), 100 seed mass (37.4g), shelling percentage (71.5) and number of pods plant\(^{-1}\) (15.8) of the confectionery peanut (ICGV 92206) were significantly higher as compared to TMV 2. Similarly, significantly higher pod yield of 2.35 t ha\(^{-1}\) was observed with the variety ICGV 86742 compared to the local control Yue You 116 (Liang Xuangquiang \textit{et al.} 1996). Studies conducted by Mohiuddin and Ghosh (1996) highlighted that yield and yield components were varied greatly among the six peanut varieties. Cultivar JL 24 recorded significantly higher number of pods plant\(^{-1}\) (13), kernels plant\(^{-1}\) (20) and higher pod yield of 2612 kg ha\(^{-1}\) as compared to other varieties. In a field experiment conducted with fifteen-confectionery peanut varieties under rainfed condition, significant difference in yield attributes were observed among the peanut varieties and highest pod yield (2.4 t ha\(^{-1}\)) was noticed in ICGV 90173 peanut variety (Novita Nurgrahaeni \textit{et al.} 1996). Ramesh Thatikunta and Durgaprasad (1996) reported that TG 26 and K 134 varieties yielded significantly more pod yield (2.41 and 2.23 t ha\(^{-1}\) respectively) compared to TMV 2 (1.22 t ha\(^{-1}\)). However, the yield superiority of these two genotypes was not reflected in their ancillary characters.

Bandopadhyay \textit{et al.} (1998) compared the performance of TG 194, JL 24, TAG 24 and TGS 1 peanut varieties during the Kharif season of 1991 and 1992. The results showed that TG 194 had significantly higher number of pods plant\(^{-1}\) (21.85), shelling percentage (70) and pod yield of 2500 kg ha\(^{-1}\) as compared to other varieties.

Peanut cultivar TMV 2 recorded significantly higher pod yield of 3618 kg ha\(^{-1}\) as compared to JL 24 and ICGV 86564. In another experiment, the confectionery variety GG 20 had significantly higher pod yield which was 21.7 per cent higher than ICGV 86564 (AICORPO, 1999). In Orissa, Shahu \textit{et al.} (1999) compared five peanut genotypes and the highest pod yield of 836 kg ha\(^{-1}\) and shelling turn over of 69.2 per cent was observed with ICGS 11 peanut as compared to other peanut varieties. Somnath, a confectionery peanut variety gave significantly higher pod yield (3110 kg ha\(^{-1}\)), shelling percentage (75) and hundred-kernel weight (66.7g) compared to K 134 (AICORPO, 2000). A new high yielding peanut variety AK 159 was compared with TAG 24, TG 26 and JL 24 for Vidarbha region of Maharashtra and it was found that cultivar AK 159 yielded 2.39 t ha\(^{-1}\) which was 38.5, 33.1 and 22 per cent more than that of TG 24, TG 26 and JL 24, respectively (Deshmukh \textit{et al.} 2000). Subramaniyan \textit{et al.} (2000) evaluated the performance of confectionery peanut varieties at Vridhachalam and reported that ICGV 86564 recorded the maximum plant height, number of pods/plant, 100 kernel weight, shelling and sound matured kernels (SMK) percentage. As a result, the variety ICGV 86564 significantly recorded a higher pod yield of 2493 kg ha\(^{-1}\) compared to B 95 (2371 kg ha\(^{-1}\)). Kale \textit{et al.} (2002) conducted a study with high yielding peanut varieties in farmer’s fields at Kolhapur of Maharashtra and recorded the ever-highest pod yield in India of 10.175 kg ha\(^{-1}\) and 10.542
kg ha\(^{-1}\) respectively with TAG 24 and TG 26 peanut varieties.

### 2.3. Quality parameters

Experiment conducted at Akola during summer season indicated that significantly higher oil content of 48.9 per cent was observed in ICGC 87189 peanut than that of other peanut genotypes viz., J 19 Sel. 7-9-5 and ICGV 86309 (Bhole Rao et al. 1993). Roseane Cavalcanti dos Santos (1995) compared the performance of three Argentinean peanut cultivars and found that Colorado Irradiado recorded significantly higher oil, protein, iodine value and O/L ratio compared to other cultivars. Significant difference in oil content between the fifteen peanut varieties was observed at West Bengal during post rain / summer season and the variety TG 19A gave significantly higher oil yield of 0.90 t ha\(^{-1}\) compared to other varieties (Samui and Minajur Ahasan, 1995). Bandopadhyay et al. (1998) reported significant variation in oil content, oil yield and protein content among the different peanut varieties. Liang Xuanquiang et al. (1999) evaluated two peanut genotypes and concluded that Yue You 79 had significantly higher oil content of 52.0 per cent, protein content of 32.5 per cent, O/L value of 1.67 as compared to Yue You 5. Manivel et al. (2000) compared the performance of fifteen confectionery peanut genotypes at Junagadh and the genotype PBS 29036 gave significantly lower oil content of 47.3 per cent, higher sucrose content of 9.74 per cent, higher free amino acid content of 0.37 per cent and reducing sugars of 0.27 per cent compared to other genotypes. Motagi et al. (2000) studied oil recovery and quality of different peanut genotypes at Patancheru and found that D 39 recorded the highest oil yield of 1.75 t ha\(^{-1}\), high O/L ratio of 1.78 revealing better nutritional and keeping quality as compared to other genotypes. Bold seeded peanut accessories for confectionery attributes were evaluated by Rajagopal et al. (2000) and the results revealed that for confectionery purpose, besides higher 100 seed mass and SMK, seeds with lower oil content, high protein and high sucrose contents preferred. The accessions NRCGs 2863, 5505, 7276 and 8939 gave significantly higher protein, higher sucrose and low oil content than other accessions and were identified for confectionery purpose.

### 3. Influence of plant population

One of the critical factors limiting yield of peanut is inadequate plant density. Proper crop geometry facilitates sufficient interception of sunlight and satisfactory absorption of nutrients and water from the soil due to proper development of root system.

#### 3.1. Growth parameters

The source sink dynamics regulate crop yield, which were generally influenced by the genetic make up and the crop environment (spacing). In spite of the general belief that the source (leaves) in peanut is well developed and non-limiting, environmentally induced difference exist. Leaf area per plant and biomass yield was significantly influenced by the different row and plant spacing (Bell et al. 1987). Higher plant height, LAI and DMP were recorded at a population level of 3.33 lakh plants ha\(^{-1}\). LAI and DMP were stabilized on further increase of plant population (Patel et al. 1991). Higher levels of defoliation in lower level of plant population than in the higher population suggested the importance of LAI in the accumulation of photosynthetic products, branches and roots of peanut. A 100 percent defoliated plants was recorded in the 13 plants per square meter (Tarimo and Mkesle, 1987). The investigation on the response of peanut growth to that of density and spatial ratio (Bell et al. 1987) revealed that the biological yield was unresponsive to the spatial ratio but increased markedly with increase in density up to 5.8 lakh plants per hectare. Closer row spacing increased the height of main stem and
length of lateral branches in peanut (Mozingo and Steele, 1987). Reddy and Giri (1989) observed and reported contradictorily that lower plant density of 1.5 lakhs produced higher dry matter accumulation and LAI. More denser crop of peanut extracted water from lower depth sooner than less denser crops. This leads to more rapid leaf area development prior to early pod filling stage (Wright and Bell, 1992). Increased row spacing from 30 to 75 cm enhanced the plant height from 37.34 to 49.48 cm as reported by Hameed Ansari et.al. (1993).

Pannu et.al. (1989) observed significantly higher dry matter production in peanut with a wider spacing of 22.5 x 10 cm compared to closer spacing of 15 x 15 cm. Similarly, Hameed Ansari et.al. (1993) found that increasing the row spacing to 75 cm resulted in higher plant height (49.48 cm) than that of closer row spacing of 30.45 and 60 cm during summer season. In contrast, Patra et.al. (1999) reported that shoot dry weight of peanut at early stages did not vary much due to different spacing, but at later stages, 25 x 12 cm spacing recorded significantly higher shoot dry weight, nodule number and nodule dry weight compared to 50 x 6 cm spacing at Kalyani during summer season. Whereas, Subrahmaniyan et.al. (2000) studied spacing requirement for confectionery peanut varieties and reported that wider spacing of 65 x 15 cm registered maximum plant height of 49.80 cm than that of closer spacing of 30 x 15 cm and 45 x 15 cm (46.72 and 47.50 cm respectively). Research conducted on peanut variety TAG 24 with three different spacing viz., 30 x 10 cm, 25 x 10 cm and 20 x 10 cm in sandy clay soils during summer season revealed that wider spacing of 30 x 10 cm significantly increased all the growth parameters viz., plant height (12.44 cm), number of branches plant$^{-1}$ (9.39) and spread (27.40 cm) over the rest of the spacing (Ramesh and Sabale, 2001 b).

3.2. Yield and yield components: It is generally recognized that yield increase were associated to crop geometry. Yield is a function of inter plant and intra plant competition and as such there is a considerable scope for increasing yield by adjusting plant population to an optimum level (Lomte and Khuspe, 1987). Ahmed et.al. (1986) earlier observed that peanut grown at different spacing recorded an average pod yields ranging from 1.39 to 1.58 t ha$^{-1}$, respectively, yields were similar when rows were 20 and 30 cm apart but higher than in rows 40 cm apart. Similarly peanut yield decreased due to increased spacing between plants from 10 to 15 and 20 cm. However, Deshpande et.al. (1986) reported that peanut yields were higher when planted in rows, 40 cm apart than in rows 50 or 60 cm apart. Throat and Patil (1987) found that yields at spacing of 30 ˚ 15, 45 ˚ 15 and 30 ˚ 30 cm were 1.40, 1.36 and 1.14 t ha$^{-1}$, respectively. Peanut cv. JL. 24 grown at a spacing of 30 ˚ 15 or 45 ˚ 10 cm registered yields of 2.04 and 2.09 t ha$^{-1}$ respectively (Patel and Patel, 1988). They were supported by Muhammed Aslam et.al. (1988); Faleiros et.al. (1988); Kanesiro et.al. (1988); Agasimani et.al. (1989); Munda and Patel (1989) and Patel and Parmer (1989). Rajagopal and Palchamy (1990) reported a higher pod yield under the population of 2.2 lakh plants ha$^{-1}$ in flat ridges and furrows system of planting. They also concluded that population of 3.3 lakh plants ha$^{-1}$ at a spacing of 75 cm between the furrows, 22.5 cm between the paired rows with 12 cm intra row spacing registered the highest net return. Patel et.al. (1991) contradicted to the earlier reports and reported that peanut sowing in rows of 30, 45 or 60 cm had no effect on average pod yields, however, significant interaction was noticed when the inter or intra row spacing of peanut were increased (Pawar and Bhosale, 1992). Similar
observation was also reported by Jadhao et al. (1992). However, Nandania et al. (1992) recorded increased pod yield with decreased inter row spacing. Sandhu and Hundal (1993) concluded that no significant influence on pod yield of peanut was obtained with inter row spacing alterations between 20 and 40 cm. Hameed Ansari et al. (1993) recorded increased pod yield at row spacing of 30 cm than at 45, 60 or 75 cm.

Rama Rao et al. (1983) opined that maximum number of total pods plant\(^{-1}\) (24.1), filled pods plant\(^{-1}\) (15.7), pod weight plant\(^{-1}\) (14.71 g) and pod yield of 37.3 \(\text{q ha}^{-1}\) was observed under 30 x 10 cm spacing and it was higher than that of 20 x 10 cm and 10 x 10 cm spacing. Sambasiva Reddy et al. (1983) observed the highest number of filled pods plant\(^{-1}\) with crop geometry of 60 x 18.8 cm and it was significantly higher than 45 x 25 cm spacing. In contrast, experiment conducted at Raigad during Rabi season to examine the performance of improved varieties of peanut under various levels of plant population revealed that significantly higher dry pod yield of 30.7 \(\text{q ha}^{-1}\) was recorded with closer spacing of 30 x 10 cm than the wider spacing of 45 x 15 cm and 30 x 30 cm (Kalra et al. 1984). Similarly, the results of the experiment conducted on response of peanut to plant spacing during Kharif season indicated that 20 x 15 cm spacing recorded the highest pod yield of 40.9 \(\text{q ha}^{-1}\), which was at par with 20 x 10 cm and significantly superior over wider spacing. Lower pod yield of 31.5 \(\text{q ha}^{-1}\) and 31.4 \(\text{q ha}^{-1}\) was recorded with the closer spacing of 10 x 5 cm and wider spacing of 40 x 20 cm, respectively (Agasimani, 1989). Pannu et al. (1989) observed that 22.5 x 10 cm spacing gave the highest pod yield compared to 15 x 15 cm spacing. Higher yield of peanut is contributed by two factors and those are yield per plant and number of plants per unit area. Providing adequate spacing and encouraging yield contributing components had increased the pod yield (Rajagopal and Palchamy, 1990). Dwivedi and Gautam (1992) observed significantly higher pod yield under wider spacing of 40 x 20 cm as compared to 30 x 20 cm spacing.

Similarly, Jadhao et al. (1992) concluded that 30 x 15 cm and 45 x 10 cm spacing gave higher peanut yield than 30 x 10 cm, 30 x 30 cm, 45 x 15 cm and 45 x 20 cm spacing during summer season. Hameed Ansari et al. (1993) stated that increased row spacing of 75 cm resulted in more number of pods plant\(^{-1}\) (61.83), pod length (3.25 cm), seed weight plant\(^{-1}\) (75.83 g) and pod yield of 2332 kg ha\(^{-1}\) compared to other closer row spacing. Field trials conducted at Jagtial of Andhra Pradesh to study the performance of Spanish peanut TG 26 under different plant densities revealed that the spacing of 30x7.5 cm gave more number of matured pods plant\(^{-1}\) (30), higher pod yield (2.78 t ha\(^{-1}\)) and haulm yield (2.82 t ha\(^{-1}\)), though it was at par with a spacing of 22.5 x 7.5 cm (Krishna et al. 1995). Patel and Patel (1995a) evaluated different row spacing of peanut and observed that pod yield at row spacing of 15 and 22.5 cm were significantly higher than at 30 cm row spacing. However, haulm yield was not affected significantly by different row spacing.

Shelling percentage was comparatively higher at wider spacing (50 cm row to row). Pod and kernel yields were significantly higher at 40 cm row spacing over 30 and 50 cm row spacing (Choudhury et al. 1997). Ghosh et al. (1997) stated that the rectangularity at 1:2 (15 x 30 cm) gave significantly higher pod yield plant\(^{-1}\) when compared to other rectangularity of 1:2 (22.5 x 45 cm), 1:4 (15 x 60 cm) and 1:4 (11.25 x 45 cm). The rectangularity 1:4 (15 x 60 cm) gave the lowest pod yield. Similarly, closer spacing of 30 x 10 cm produced significantly higher pod yield of 2696 kg ha\(^{-1}\) as compared to 30 x 15 cm spacing. In
another study, significantly higher pod yield was noticed at 30 x 15 cm by 25 per cent and kernel yield by 35 per cent over the wider spacing of 60 x 15 cm. Closer spacing also improved the other parameters like shelling percentage, hundred-kernel weight and SMK percentage (AICORPO, 1999). Closer spacing of 25 x 10 cm significantly gave higher pod and haulm yield of 2694 and 4397 kg ha⁻¹ respectively as compared to 30 x 10 cm, 20 x 10 cm and 15 x 10 cm spacing (Meyyazhagan et.al. 1999). The results of field experiment conducted by Patra et.al. (1999) concluded that 25x 12 cm spacing gave significantly higher dry weight of pods plant⁻¹ (4.88 g) and pod yield (2145 kg ha⁻¹) than that of 50 x 6 cm spacing. Kaushik and Chaubey (2000) also found that pod yield of peanut was significantly affected by row spacing. The pod yield of 30 cm inter row spacing was significantly higher than that of 45 cm inter row spacing (18.64 and 14.71 q ha⁻¹ respectively). Subrahmaniyan et.al. (2000) found that lower population of 1,11,111 plants ha⁻¹ (60 x 15 cm) registered higher number of matured pods plant⁻¹ (12), 100 kernel weight (65.04 g), shelling percentage (66.73) and SMK percentage (84.91) over rest of the spacing. However, the highest dry pod yield of 3165 kg ha⁻¹ was recorded under the spacing of 30 x 15 cm by virtue of more number of plants ha⁻¹ (2,22,222 plants ha⁻¹)

3.3. Quality attributes: Hameed Ansari et.al. (1993) studied the impact of row spacing on oil content in bunch type peanut variety G 17 and found that wider row spacing of 75 cm recorded higher oil content of 47.93 per cent compared to closer spacing of 30 cm while, Patel and Patel (1995b) reported that inter row spacing had no significant effect on seed oil content. However, oil yield was significantly higher at closer spacing viz., 15 and 22.5 cm than at 30 cm inter row spacing. Kaushik and Chaubey (2000) also found that inter row spacing did not exert any significant influence on oil content of peanut. In contrast, Ramesh and Sabale (2001b) compared three population densities in TAG 24 bunch type peanut variety and found that protein percentage and oil content increased with decrease in population per unit area. Higher protein yield and oil percentage were observed with 0.33 million plants⁻¹ compared to 0.40 and 0.50 million plants ha⁻¹.

It is generally recognized that yield increase were associated to crop geometry. Yield is a function of inter plant and intra plant competition and as such there is a considerable scope for increasing yield by adjusting plant population to an optimum level (Lomte and Khuspe, 1987). Ahmed et.al. (1986) earlier observed that peanut grown at different spacing recorded an average pod yields ranging from 1.39 to 1.58 t ha⁻¹, respectively, yields were similar when rows were 20 and 30 cm apart but higher, than in rows 40 cm apart. Similarly peanut yield decreased due to increased spacing between plants from 10 to 15 and 20 cm. However, Deshpande et.al. (1986) reported that peanut yields were higher when planted in rows, 40 cm apart than in rows 50 or 60 cm apart. Throat and Patil (1987) found that yields at spacing of 30´ 15, 45´ 15 and 30´ 30 cm were 1.40, 1.36 and 1.14 t ha⁻¹, respectively. Peanut cv. JL. 24 grown at a spacing of 30´ 15 or 45´ 10 cm registered yields of 2.04 and
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4. **Nutrient Management**: Peanut is called as an unpredictable legume, since its behaviour to nutrient application is always not optimistic. Excessive application of nitrogen and potassium often resulted in an excessive vegetative growth. Considering the availability of the major elements in the soil and quantum of losses due to leaching and/or fixation of the individual elements expected, a proper method and the time of nutrient application is the need of the hour. This fact calls for a concerted study on the possibility of more effective utilization divided dosages like basal and top dressing.

4.1. **Organics**: Pre and post harvest invasion of *Aspergillus* and the subsequent production of toxic metabolites is a serious and constant feature of peanut production under the high moisture conditions. The species of Trichoderma are known to be potential bio control agents for several soil borne pathogens. Padmakumari and Balakrishnan (1987) reported that addition of neem cake to soil enhanced the population of Trichoderma spp. Chakrabarti and Sen (1991) found that organic amendment acted as a source of substrate for growth and multiplication of bio agent. Karthikeyan (1996) found that application of neem cake along with *Trichoderma viride* and carbendazim gave good disease control against soil borne pathogen in peanut. Desai et al. (2000) reported that Trichoderma had the strong antagonism to *Aspergillus flavus* infecting peanut and some of these isolates have been used as potential biocontrol agents in green house and field experiments.

Application of organic combination of nutrients contributed to the inhibition of nitrogen accumulation in rice grain yield and consequently, the superior grain quality traits was noticed as compared to control treatment (Nakagawa et al. 2000). Similarly Kuruma and Ichimara, 2000 also reported superior physical quality parameters due to organic nutrients application. Application of castor cake or neem cake @ 1.0 t ha\(^{-1}\) improved the quality characters of confectionery peanut varieties. Further, it reduced the aflatoxin content in the peanut kernels due to the antagonistic effect on *Aspergillus spp.* (Bordar, 2001). Soil application of *Trichoderma viride* @ 100 g m\(^{-2}\) + neem cake @ 100 g m\(^{-2}\) to bunch peanut significantly increased growth attributes viz., shoot length (21.23 cm), root length (9.9 cm) and nodules plant\(^{-1}\) (44) as compared to other organics (Gayathri Subbaiah and Indra, 2003). In addition, neem cake proved to be an effective and best substrate for multiplication of *Trichoderma viride* followed by peanut cake. *Trichoderma*
viride sporulated well in neem cake used as substrate which recorded 324 x 10^5 cfu g^-1 15 days after inoculation, followed by peanut cake which recorded the population of 275.67 x 10^5 cfu g^-1. Significantly higher shelling percentage (69.6), pod yield (2163 kg ha^-1) and harvest index (37) was also observed with the same treatment. Application of press mud in combination with poultry manure, farm yield manure and neem cake was found to be superior with 7.4 points of organoleptic evaluation with respect to colour, texture, taste and over all acceptability of rice when compared to other organics. Further, it was reported that combined application of press mud with neem cake and poultry manure was found to be superior in terms of better kernel length after cooking (9.8 mm), length to breadth ratio (0.35), elongation ratio (1.52) and head rice recovery (71.9 per cent) (Satheesh and Balasubramanian, 2003).

4.2. Inorganic

4.2.1 Nitrogen: Nitrogen in general is the major structural constituent of the plant cell. It plays an important role in plant metabolism by virtue of being an essential constituent of metabolically active components like amino acids, protein, nucleic acid, flavins, purines and pyrimidines, nucleotides, enzymes and alkaloids. The biological role of N is evidenced through the chlorophyll in harvesting solar energy, phosphorylated compounds in energy transformation, nucleic acid in the transfer of genetic information and regulation of the cellular metabolism and biological catalysts (Mahapatra et. al. 1985). Erect bunch varieties of peanut are popular because of their short duration and the case with which they could be harvested. Often, the better response of these varieties to applied nitrogen revealed that nitrogen limitations could inhibit the growth and productivity (Cox et. al. 1982). Patel et. al. (1983) compared three levels of nitrogen to summer peanut at Junagadh and reported increase in plant height, plant spread and number of primary branches plant^-1 with each successive increase in nitrogen levels at 12.5, 25 and 37.5 kg ha^-1. Further, peanut variety TG 17 responded up to 25 kg N ha^-1 and registered higher number of pods plant^-1 (13.8) and pod yield of 14.2 g plant^-1. It was concluded that application of 25 kg N ha^-1 was optimum and also economical. Any increase in fertilizer dose beyond 25 kg ha^-1 tended to depress the yield. Application of ammonical N at 30 kg N ha^-1 combined with rhizobial inoculation had increased the nodule number, root and shoot growth and total dry matter plant^-1 (Raja rajeswari et. al. 1987). At Akola, different levels of nitrogen were tried viz., 0, 15 and 30 kg ha^-1 in peanut during summer season and the results revealed that application of N at higher dose did not significantly affect dry matter accumulation and yield attributes at harvest (Chawale et. al. 1993). Chavan and Patil (1995) compared four peanut varieties with three levels of nitrogen and reported that the variety UF 70103 showed a consistent and significant response to increased levels of nitrogen up to 40 kg ha^-1. The variety JL 24 showed a significant yield up to 25 kg ha^-1 while SB XI was not consistent in its response pattern. According to Sukanya et. al. (1995), increasing level of nitrogen increase the nodule number, nodule mass, total dry mass, total nitrogen content, pod yield and harvest index in peanut. Similarly, Barik et. al. (1998) reported that dry matter production, LAI and plant height were increased significantly with the enhanced rate of nitrogen supply at various stages of growth up to harvest and the highest value was recorded with 120 kg ha^-1. However, the results of the research experiment conducted by Edna Antony et. al. (2000) revealed that LAD, LAI and leaf NAR increased with an increase in nitrogen dose in all genotypes studied and concluded that 25 kg N ha^-1 was necessary for optimal yield. Yield of peanut tended to decrease with higher dose of N beyond 25 kg ha^-1. Gogoi et. al.
(2000) compared different levels of N viz., 0, 20, 40, 60 and 80 kg ha$^{-1}$ and observed that increased level of nitrogen application significantly increased the number of branches plant$^{-1}$, number of pegs plant$^{-1}$, number of pods plant$^{-1}$ and shelling percentage. However, significant increase in yield and yield attributes were noted only up to 40 kg ha$^{-1}$ which was at par with 60 kg ha$^{-1}$. Similarly, Deka et al. (2001) indicated that increasing level of nitrogen increased the nutrient uptake up to 40 kg ha$^{-1}$ and resulted in significantly higher kernel and haulm yield of peanut.

Similarly, plant height, leaf area and dry matter accumulation plant$^{-1}$ were increased with increasing rates of N. Nitrogen rates up to 60 kg N ha$^{-1}$ significantly increased the pod yield of peanut and being a legume crop, it did not respond to applied N beyond 60 kg N ha$^{-1}$ (Singh and Singh, 2001).

### 4.2.2 Phosphorus

Phosphorus being a leguminous crop, requires small quantity of nitrogen, but being rich in protein and oil, it requires higher amounts of phosphorus and other elements like K and S. Budhar et al. (1986) stated that the magnitude of response to P application for bunch peanut under irrigated condition depends on the initial available phosphorus status of the soil. They observed that the response to P application was more in low P status soil (up to 120 kg ha$^{-1}$), while for medium P status, 60 kg ha$^{-1}$ was found to register the highest response. Tomar et al. (1983) reported that phosphorus application significantly increased the yield and yield attributes and observed a significant increase in dry pod yield with successive increase in phosphorus levels up to 40 kg P$_2$O$_5$ ha$^{-1}$. Higher benefit was obtained in 60 kg P$_2$O$_5$ ha$^{-1}$, but was on par with 40 kg P$_2$O$_5$ ha$^{-1}$. Raju et al. (1985) studied the response of various levels of phosphorus and observed significant increase in plant height, number of branches per plant and LAI with increase in the level of phosphorus. Similarly mature pods per plant, 100 kernal weight and shelling percent also increased with increase in phosphorus level. Kulkarni et al. (1986) in an experiment noticed that phosphorus application (up to 50 kg P$_2$O$_5$ ha$^{-1}$) increased the number and weight of nodules and dry matter accumulation in the plant. Chauhan et al. (1987) observed a significant increase in plant height and number of branches per plant up to 40 kg P$_2$O$_5$ ha$^{-1}$, there after the trend declined.

### 4.2.3 Potassium

Potassium is a third major nutrient in plant nutrition after nitrogen and phosphorus. It plays a unique role in many vital functions in peanut plant. Purushothaman Nair et al. (1982) reported that potassium application increased the dry mater production and pod yield of peanut. Similarly, Kulkarni et al. (1986) observed that application of 50 kg K$_2$O ha$^{-1}$ had increased the number and weight of nodules, N content, dry matter accumulation and pod yield of peanut. Potassium nutrient requirement of peanut was highest between 60 and 90 days after sowing (Nagarajan and Kailashkumar, 1986). Mohandass et al. (1987) observed that K supply had enhanced the leaf area, leaf area duration, which resulted in higher net assimilation rate. According to Jana et al. (1990), addition of K up to 49.8 kg ha$^{-1}$ had increased the number of pods plant$^{-1}$, number of seeds pod$^{-1}$, 100 seed weight, pod and oil yields. The response was quadratic and also influenced the K content of seeds. The pod and haulm yield of peanut increased significantly with application of 40 kg K$_2$O ha$^{-1}$ over lower dose and further increase beyond this level did not increase the yield. Oil content in kernel increased with graded levels of K and the effect was marked at 60 kg K$_2$O ha$^{-1}$. However, protein content and protein yield increased only with application of 40 kg K$_2$O ha$^{-1}$ (Deshmukh et al. 1992). Hameed Ansari et al. (1993) found that application of potassium up to 45 kg ha$^{-1}$ significantly
improved the pod yield (3392 kg ha\(^{-1}\)) and its contributing characters compared to lower dose of 15 and 30 kg ha\(^{-1}\). Application of K also recorded higher uptake of NPK and also increased the pod and kernel yield of 232 g m\(^{-2}\). Quality parameters were also enhanced by the application of K, which reflected in oil and protein content (Lakshmamma et al. 1996). Application of potassium at 100 kg ha\(^{-1}\) significantly increased the plant height, nodule weight, pod number, pod and haulm yield of peanut and also increased the concentration of K and S at 45 days after emergence and their uptake by peanut at harvest (Singh and Vidya Chaudhari, 1996). Subrahmaniyan et al. (2000) observed linear response of confectionery peanut varieties viz., ICGV 86564 and B 95 to NPK fertilizers. Increased dose of NPK fertilizers up to 150 per cent significantly recorded the maximum plant height, number of matured pods plant\(^{-1}\), 100 kernel weight, shelling percentage, SMK percentage and pod yield of peanut. Significant increase in pod yield of peanut was recorded at fertilizer level of 30:60:0 kg NPK ha\(^{-1}\) and increase in yield was 30 per cent higher than lower level of fertilizer doses (Vinod kumar et al. 2000). Dutta et al. (2003) reported that potassium content both in kernel and haulm was significantly affected by the different levels of potassium and maximum was observed with application of 50 kg K\(_2\)O ha\(^{-1}\). Application of graded levels of potassium produced significant difference in uptake of N, P and K and significantly increased due to higher doses of potassium application (50 kg K\(_2\)O ha\(^{-1}\)).

**4.2.4 Split application of nitrogen and potassium** : In India, the most common recommendation is to apply the full dose of N and K as basal dressing. However, split applications of N and K have been emerging for peanut plants. Application of K along with N in two to three splits not only increase the productivity but also enhance the quality parameters (Deshmukh et al. 1993). Loss of K due to leaching can be serious in coarse textured sandy soils in high rainfall areas. In such situations, it may be profitable to apply K in splits. Split application of K in two to three doses has been reported to be superior to a dose of basal application in light to medium textured soils containing kaolinite and illitic clay minerals and in region of high rainfall (Goswami and Khera, 1981).

Padole and Deshmukh (1982) observed that there was an increased uptake of N by kernel when the nutrients were applied by split doses. According to Reddy (1982), split application of N (half at sowing and half at 60 DAS) did increase the pod yield of peanut by 28 per cent over control. Sarmah et al. (1982) reported in sandy loam soil with medium available K that application of 80 kg K\(_2\)O ha\(^{-1}\) as split application (half the dose as basal and the remaining half as top dressing at 25 DAS) resulted in highest haulm and pod yield. According to Zakaria (1986), split application of nitrogen through soil on 30, 60, and 90 DAS recorded the highest pod yield than a single application. Badiger et al. (1988) obtained an extra production of 5.7 q ha\(^{-1}\) of kernel over basal application, when additional application of K (11.2 kg K\(_2\)O ha\(^{-1}\)) at the time pegging in addition to basal application of N was done. Similarly, Chitkala Devi et al. (1988) reported that application of N and K in two splits (50 per cent basal + 50 per cent top dressing on 30 DAS) recorded the highest number of filled pods plant\(^{-1}\) and pod yield than full basal application. Hameed Ansari et al. (1993) reported that increased fertilizer dose up to 50:75:30 kg NPK ha\(^{-1}\) increased seed yield and oil content of peanut and further increment of fertilizer did not have economical effect on seed yield and oil content. Chinnasamy (1993) reported that application of 50 per cent of N and K as basal and 50 per cent in three splits viz., 25 per cent on 25 DAS (soil), 12.5 per cent on 45 DAS (soil) and 12.5
per cent on 60 DAS (foliar) has favourably influenced the growth attributes and yield of peanut. Deshmukh et al. (1993) reported that pod and haulm yield and total nutrient uptake of NPK in peanut were significantly increased with the split application of 75 per cent K at sowing and 25 percent at flowering stage. Ponnuswamy et al. (1996) reported that 150 per cent recommended dose of K (79 kg ha⁻¹) applied in two equal splits viz., half at basal and remaining half at 40 DAS gave significantly higher dry pod yield of 2383 kg ha⁻¹. Subrahmanian et al. (2000) observed linear response of confectionery peanut varieties viz., ICGV 86564 and B 95 to NPK fertilizers. Increased dose of NPK fertilizers up to 150 per cent significantly recorded the maximum plant height, number of matured pods plant⁻¹, 100 kernel weight, shelling percentage, SMK percentage and pod yield of peanut. Significant increase in pod yield of peanut was recorded at fertilizer level of 30:60:30 kg NPK ha⁻¹ and increase in yield was 30 per cent higher than lower level of fertilizer doses (Vinod kumar et al. 2000).

4.2.5 Effect of NPK: Jadhar and Narkhede (1980) reported that the number of developed pods per plant, pod yield and oil content in peanut were influenced significantly by N and P application. The oil content decreased slightly with increase in the level of N but slightly increased the protein content. Studies carried out by Devarajan and Kothandaraman (1982) on P and K nutrition on peanut, reported that the application of phosphorus and potassium significantly increased the yield of pods and shelling percentage and the highest pod yield was obtained by the combined application of 60 kg P₂O₅ and 90 kg K₂O ha⁻¹. The phosphorus and potash application increased nutritional value without altering the pod yield of peanut. However, P and K had antagonistic effect on their contents in kernels of peanut grown in summer season, on soils having medium status of available P and K content (Patel and Patel, 1988). Narasimhulu et al. (1982) stated that time of nutrient supply considerably influenced the productivity of peanut, especially on light soils where there was loss of nutrients by leaching. Hence, greater pod yield of peanut was recorded when 20, 70 and 25 N, P, K kg ha⁻¹ respectively was applied as basal and the remaining 10 kg N at 30 days after sowing. Rengasamy (1986) observed that hundred kernal weight was increased by super digested form of NPK combined with bacteria fertilizer. Narasa Reddy et al. (1987) reported that it is economical to adopt a fertilizer schedule of 30 N+10 P + 25 K + 500 gypsum kg ha⁻¹ with a plant density of 3.33 lakh plants ha⁻¹ (30 x 10cm) in sandy loam soil. Athmanaban (1989) concluded that under peanut based intercropping system, application of either composted coir pith +NPK or enriched FYM + N can be recommended to the cropping system viz., peanut + green gram (4:1) in view of favourable influences on growth, yield components, monetary benefit and maintenance of soil fertility.

4.2.5.1 Nutrient content and uptake: Balakrishnamoorthy (1967) observed that application of K had increased the uptake of N. Application of K₂O at 200 kg ha⁻¹ resulted in 173.8 kg N uptake ha⁻¹ at seed ripening compared to control (110.7 kg ha⁻¹). Similarly, Devarajan (1976) reported that application of K in red calcareous soil significantly had increased the N content of haulm from 1.21 to 1.51 per cent, but on the other hand, application of K had decreased nitrogen content of shell from 1.73 to 1.52 per cent. Rana et al. (1984) studied the response of peanut to fertilizer application revealed that application of increased dose of NPK (20: 60: 40 kg ha⁻¹) fertilizers alone or in combination significantly increased the pod yield of peanut. Successive increase in their rates resulted in significant increase in pod yield. Dubey and Shinde (1986) reported that application of
fertilizer K increased uptake of nutrients by peanut. Removal of N, P and K were highest when full dose of K was applied at sowing and the next best treatment was application of 75 per cent K at sowing and 25 per cent at flowering stage.

The content of N and P in kernel were higher than that of haulm, which might be due to translocation of nitrogen and phosphorus to kernels where these were accumulated in the form of protein and fat. On the other hand, potassium content was higher in the haulm than in kernels, which may due to better utilization of potassium by plants meristematic tissues for peanut (Jain and Dixit, 1987). Patel and Patel (1988) reported that application of K at 60 kg ha⁻¹ increased N and K content, which altered the yield of peanut. Application of K, in general increased N, P and K content in all the plant parts at harvest stage. On an average 137.31, 16.6 and 63.34 kg N, P and K ha⁻¹, respectively were removed by peanut crop (Deshmukh et al. 1993). A field study on the effect of lime and N on nutrient uptake in peanut and the results revealed that with each increase in the dose of nitrogen, nitrogen uptake increased significantly up to 40 kg ha⁻¹, which was at par with 60 kg ha⁻¹ (Deka et al. 2001). Badole et al. (2003) studied the effect of organic and inorganic fertilizer on the uptake of peanut at Parbani during summer season in the clay loam soil and found that integrated nutrient supply system (50 per cent of recommended of fertilizer through organic and remaining by inorganic fertilizer) significantly improved the uptake of peanut compared to control. Application of potassium produced significant difference in the case of total N, P and K uptake and the uptake was significantly increased due to higher dose of potassium application at 50 kg ha⁻¹, which was at par with 40 and 30 kg K ha⁻¹ (Dutta et al. 2003).

4.3 Foliar spray of nutrients: In the experiments conducted at various Agricultural Research stations of TNAU on the combined nutrient spray, the peanut yield was increased to 20 per cent compared to control (Anon 1985). Application of naphthalene acetic acid at 40 ppm increased the flower, pod weight per plant and total yield to the extent of 41.5 per cent more than control (Valliappan et al. 1985). Foliar application of borax 0.1 and 0.2 per cent increased peanut yields by 9.0 per cent (Zhang et al. 1989). Nagaraj (1987) stated that application of Mo, Mn, Fe, Mg and B each at 3 rates through foliage twice to peanut had not significantly increased the protein content. Mo, and Mg increased soluble sugar content while Mn increased ash content. NAA spray at 15 ppm increased peanut yields by 15 per cent over control (Thimmegowda et al. 1985). Store et al. (1989) stated that foliar spray of cycocel applied at 20 DAS have increased the number of flowers, pegs and pods per plant. Walker et al. (1982) observed that foliar application of K not only failed to increase the yield but also resulted in non significant difference between soil and foliar application, but foliar spraying of 0.5 per cent K proved more effective in maintaining plant and soil water status (Senthilkumar, 1990). Golakiya and Patel (1988) reported that foliar spraying of two per cent K improved the productivity by four to eight per cent over control.

4.4 Gypsum Application to peanut: Gypsum (CaSO₄·H₂O) is generally applied to peanut to improve the soil structure, soil aggregation there by enhancing the peg entry in to the soil. Application of gypsum to peanut either at sowing or early flowering time reduced soil bulk density and increased the rate of hydraulic conductivity, total porosity, aggregation and water intake rate. The improvement in the soil structural attributes might influence soil aggregation due to gypsum application (Reddy, 1986).
4.4.1 Growth characters: Peanuts possess a unique nutritional requirement in that supplemental Ca must be supplied to the “peg”, a modified stem that penetrates the soil surface to form the pod or nut. Plant height and number of branches at 30 days after sowing (DAS) recorded no significant variation due to the application of fertilizer, however, application of gypsum produced maximum plant height and number of branches contributing to maximum dry matter production (Mosha, 1986). He also concluded that application of gypsum at the time of sowing increased the nodule number per plant up to 90 DAS. Application of gypsum @ 560 kg ha⁻¹, as observed by Bell et al. (1988), registered the most frequent and significant increase in germination of peanut cultivars. Combined application of gypsum and biofertilizer – Rhizobium increased the chlorophyll concentration, N uptake, N fixation and total plant dry weight in peanut (Lee et al. 1990). However, Choi and Ryu (1991) observed that gypsum application increased S uptake but had no effect on the uptake of N, P, K, Ca or Mg. He also opined that increase in dry weight of above ground parts and roots, number of branches and number of compound leaves were positively correlated with S uptake. The experiment on effect of varying soil moisture on the extractable of gypsum amended plots conducted by Alva et al. (1991) revealed that gypsum amended plots under wettest condition increased the concentration of K and Mg in soil solution and there existed leaching of these elements from the fruiting zone of peanut. Adams and Hartzog (1980) demonstrated the importance of Ca for peanut germination and seedling survival. They also concluded that the response of peanut for application of gypsum was more when the soil Ca content was below 130 mg kg⁻¹. Gypsum application of 30 kg ha⁻¹ along with recommended urea recorded greater plant growth than when applied urea alone. More and Nalawade (1993) from a field trial contradicted to the earlier reports and concluded that gypsum application up to 400 kg ha⁻¹ did not influence the growth characters of peanut.

4.4.2 Yield and yield attributes: Increased number of pods, kernel yield and shelling percentage from earlier years were reported due to the application of gypsum at 75 kg ha⁻¹ in peanut (Loganathan and Krishnamoorthy, 1977; Adams and Hartzog, 1980 and Walker et al. 1981). Fornasieri et al. (1987) concluded the gypsum application at flowering stage increased the number of pods and nuts resulting in higher yield in peanut. They recommended to apply gypsum @ 672 kg ha⁻¹ to get increased pod yield. On further increase in the rate of gypsum application (Sistani and Morrill, 1989), the pod yield tends to decrease. Wongwiwatchai et al. (1988) concluded that the yields and shelling percentage of peanut grown at all sites did not significantly respond to the application of gypsum. However, a significant increase in 100 seed weight, shelling percentage and yield due to the application of gypsum up to 200 kg ha⁻¹. The results of experiments conducted at Jaipur (Sharma et al. 1989) showed that soil incorporation of gypsum (268 kg ha⁻¹) 30 days before sowing increased the pod yield of peanut by 890 and 520 kg ha⁻¹ over the untreated control during 1986 and 1988, respectively. Similar positive influence of gypsum on yield, total kernel content and percent mature kernel up to 672 kg ha⁻¹ were reported by Sistani and Morrill (1989), Alva et al. (1989), Lee et al. (1990) and Rao et al. (1990). Application of 250 kg gypsum per hectare at sowing and 250 kg 30 days later gave higher pod yield than a basal dose 500 kg gypsum (Devi and Reddy, 1991; Choi and Ryu, 1991 and Devi, 1991). More and Nalawade (1993), contradicted and reported non-significant influence of gypsum
application on pod number, seed yield and shelling percentage.

4.4.3 Oil content: Application of gypsum to peanut on sandy loam soils was reported to increase the oil content due to increased level of soil available sulphur. Shamsuddin et al. (1991), however, contradicted the earlier statement and reported that seed oil content was not markedly affected by application of gypsum to peanut in sandy soils. Split application of gypsum @ 250 kg ha⁻¹ each at sowing and 30 days later recorded highest oil content and oil yields (Devi and Reddy, 1991). Peanut quality (estimated by oil and protein content) was reported to be improved (Chen and Huang, 1992) under gypsum-applied plots. Seed oil and protein concentration were similarly reported to be increased due to gypsum application (Baldeo Singh et al., 1993). An oil yield of 1.13 t ha⁻¹ was obtained due to the addition of gypsum @ 500 kg ha⁻¹. The additive and complementary effects of gypsum and the S apart from Ca content was reasoned out by Chittapur et al. (1993) for the increased oil yield.

5. Irrigation Management: Water is the most important input for crop production. Crop response to all other inputs chiefly dependent on the availability of optimum quantity of water at right time. Since the available water resources are shrinking on one side and on the other hand, the national geomorphic status is increasing exponentially, there is an increased pressure on per capita requirement. In this connection, management of water may be achieved by having proper crop management, which includes conservation of moisture and improved irrigation methods. This may help to save the crop with reasonable yields under scarce conditions. The low pod yield and quality of kernels is causing concern to the farmers. The present practice of flood irrigation further aggravates aeration problem and also makes it difficult for the penetration of pegs into the soil (Chittapur et al., 1993). There are reports that the application of gypsum increased the seedling vigour, seed yield and quality by altering the soil physical characteristics (More and Nalawade, 1993). In view of the divergent nature of results, an attempt has been made to review the literature on irrigation management and other agronomic practices like gypsum application and plant densities and their effect on growth, yield and quality of peanut.

5.1 Irrigation: Water requirement of peanut varies widely for under different geo-agro-climatic conditions. Irrigation studies in peanut were taken up in recent years and the optimum available soil moisture was evaluated based on the climatic parameters, which play a predominant role in governing the water needs of crops. The water requirement for peanut ranged from 282 to 434 mm (Reddy, 1988). But the actual water requirement under field condition ranged from 455 to 600 mm (Ali et al. 1974; Cheema et al. 1974 and Samples, 1982). According to Metochis (1993), application of water in excess of requirement reduced the yield. When the water supply is adequate under irrigated conditions, peanut extracts up to 48 per cent of the water required from the upper 30 cm (Mantell and Goldin, 1964). Shalhevet et al. (1976) from the International Irrigation Center using the data from two locations in Israel showed an average removal of 36 per cent in the 0-30 cm depth, but only 7 per cent in the 120-150 cm region. Stansell et al. (1976) observed the water extraction below 60 cm depth only at 75 days after sowing. Under a limited water situation, more water extraction occurred from the 90-150 cm soil layer. Hammond and Boote (1981), Avasarmal et al. (1982) also concluded that maximum water extraction occurs in the 30-45 cm soil layer.
5.2 Scheduling of irrigation: Dastane and Sharma (1970) classified four approaches for scheduling irrigation. They are transpiration ratio, depth interval yield, soil moisture deficit and climatological approach. Among these, the climatological approach is found to be useful, feasible and practicable. In this approach, water use by crops is primarily governed by the evaporation demand of climate, provided there is an adequate moisture supply with full ground cover or the crop is actively growing. Climatological approach has been modified for irrigating the crops based on irrigation water depth and cumulative pan evaporation. The frequency of irrigation or the intervals between irrigation for the entire crop growth period can thus be computed earlier to the start of the season with the use of reasonably past years climatic mean data.

Fertilizer application has been reported to increase the water use (Bhan, 1973) and interactive effects of fertilizer and irrigation have also been shown (Babu et al. 1984; Narasimham et al. 1977). Row spacing was reported to affect the water use although there was no unanimity on which spacing helps to increase water use while, Bhan and Misra (1970) and Bhan (1973) showed that peanut grown in narrow rows of 30 cm used more water. Choy et al. (1977) reported less water use by the crop in 30 cm rows as agreed by McCauley et al. (1978). On the other hand, investigations of Reddy et al. (1978) showed the highest consumptive water use with 45 cm row spacing in comparison to 30-60 cm rows. Row orientation (Choy et al. 1977; Davidson et al. 1983; McCauley et al. 1978) in the spacing studies was reported to influence the water use. Rainfall in the semi arid regions is erratic in duration and distribution, which could lead to droughts of varying intensities and durations during the crop season. Hence, the total water use could vary with the stage of crop growth during which these droughts occur, and the water use requirements of the crop at these stages.

Peanut has specific moisture needs due to the unique feature of developing the pods underground. The quantity and quality of peanut seed is intimately related to conditions that favour the growth processes prior and during the development of seed. Proper functioning of these growth processes requires a favourable balance, controlled by the relative rates of soil moisture uptake by the roots and the water loss by transpiration. Water deficits that are a consequence of the imbalance between water uptake and transpiration, affect peanut growth depending on the stage of crop growth and the degree or intensity of drought stress. It is hence imperative that studies on water relations of peanut should include consideration of soil water availability and influence of the adequacy or lack of soil water at different growth phases on plant water status, plant growth and yield. The total water use by peanut crop is controlled by climatic, agronomic and varietal factors. Research on water management should include basic studies of soil, plant and water relations of peanut. This view was further confirmed by Tyson and Curtis (1987); Thosar et al. (1992) and Metochis (1993).

5.2.1 Irrigation scheduling on growth and development: Soil water deficiency is known to inhibit leaf expansion and stem elongation through lowered relative turgidity (Allen et al. 1976; Vivekanandan and Gunasena, 1976). The recovery in leaf area production when stress was relieved at the start of pegging was remarkable. However, this recovery was much less rapid in the case where stress was imposed during flowering to start of seed growth. The maintenance of leaf area up to the time of maturity was also remarkable for stress imposed in growth phase as compared to the fully irrigated control (Sivakumar and Sarma, 1986). Vivekanandan and Gunasena (1976) also reported reduced
leaf area index (LAI) with reduced soil water potential, with maximum LAI of 6.25 at a soil water potential of (-) 0.033 Mega Pascal (Mpa). A study on anatomy of peanut leaves under stress revealed that leaves formed under stress had smaller cells than others (Ketring, 1987 and Adamsen, 1987). Thus, the adequate growth and development of peanut is a dire necessity to get stable yields. Results from Bhavanisagar, Tamil Nadu revealed that irrigation at 0.90 IW/CPE recorded higher plant height (Anon, 1978). Krishnaswamy (1979), however, recommended 0.75 IW/CPE ratio for peanut to attain higher plant height. The increased quantity of irrigation (Rajkumar, 1986) to a tune of irrigating at 1.0 IW/CPE ratio (Madhu Sundara Rao et al. 1988) was reported to record higher plant height. Babalad and Kulkarni (1988) while irrigating at 50 per cent available soil moisture (ASM) depletion or irrigating at every week interval registered more plant height than those of the higher irrigation intervals. Thanzuala and Dhahiphale (1988) fixed an optimum ratio of 0.75 IW/CPE to peanut during summer to get increased plant height. Irrigation schedule for those periods from sowing to pod initiation and pod initiation to harvest hardly affects the plant height of peanut (Stirling et al. 1989). This insensitivity of plant height to early moisture deficit reflected the extreme plasticity of growth and development in peanut.

The number of leaves and leaf area could usually be increased by increasing the number of irrigation (Rajkumar, 1986). Similar reports of higher LAI under higher frequency of irrigation were reported by Madhu Sundara Rao et al. (1988); Babalad and Kulkarni (1988) and Mahakulkar et al. (1990). The irrigated rabi season peanut with irrigation at 0.75 IW/CPE recorded higher LAI than at 0.50 IW/CPE and was directly correlated with pod yield (Satapathy and Patro, 1992). Ramachandrappa et al. (1992) identified pod initiation and development stages as the most critical stages requiring frequent irrigations followed by peg formation and penetration stages to record more LAI and pod yield. While, stress during early stages did not affect the LAI. At Bhavanisagar, Tamil Nadu, higher dry matter production (DMP) of peanut could be achieved through irrigating at 0.90 IW/CPE ratio (Anon, 1978). The irrigation at one-week intervals also recorded a higher DMP of peanut as reported by Babalad and Kulkarni (1988). Irrigating peanut with higher levels of IW/CPE ratio (0.95) during three growth stages of sowing to pegging, pegging to pod formation and to maturity resulted in higher DMP (Kumar et al. 1987). Stirling et al. (1989) from a controlled greenhouse experiment concluded that irrigation with limited amount of at frequent intervals recorded higher DMP of peanut. Mahakulkar et al. (1990) from a trial conducted during summer season conceived that irrigation at 74 mm cumulative pan evaporation (CPE) applied to the ridge-sown peanut recorded higher DMP. Ramachandrappa et al., (1992) have well documented that the dry matter productivity of irrigated summer peanut to be more as is not subjected to the vagaries of monsoon. They were also of the view that due to the lower evapotranspiration (ET) and root development in early stages, the plant requires lower quantum of water. However, at later stages daily consumptive use increases and thus needs higher quantum in order to achieve the expected dry matter productivity.

5.2.2 Irrigation on yield: The information about the effect of scheduling irrigation at different stages of peanut on yield and yield attributes are inadequate and contradictory. Peanut yields are reported to be variable from year to year because of the large interannual variation in rainfall (Sindagi and Reddy, 1972). Bhargava et al. (1974) reported that 89 per cent of the yield variation over four regions in India could be attributed to rainfall variability in August to December growing
period. It is therefore not surprising that a large majority of agronomic investigations conducted on peanut, especially aimed at stabilizing yields. It is difficult to find uniform conclusions from studies conducted so far on the influence of soil water availability on yield at different growth phases. Since peanut is often grown at contrasting moisture regimes, measured yield responses are different. While some earlier studies showed a marked trend for higher yields with higher moisture levels (Matlock et al. 1961; Su and Lu, 1963; Goldberg et al. 1967 and Khan and Datta, 1982). Several of the recent investigations (Nageswara Rao et al. 1985; Jadhav et al. 1989 and Ramachandrappa et al., 1992) contradicted and confirmed that irrigation can be withheld during early vegetative periods with no apparent effect on pod yield of peanut. Patel and Singh (1980) inferred that supply of adequate moisture throughout the crop growth period might have promoted rapid cell division and elongation with greater impact on physiological process to increase growth and yield parameters of peanut. However, Sivakumar and Sarma (1986) concluded that the drought imposed from emergence to start of peg initiation had not affected the total dry matter produced, rate of pod growth, pod number and pod yield. Rajagopal and Palchamy (1990) was of the view that the frequent irrigation might result in continuous supply of moisture in the soil leading to root development, branching, peg and pod formation that directly hit to record higher pod yield. Subramanian et al. (1974) observed that in peanut, irrigation at 0.90 IW/CPE ratio during pod formation and maturity phase recorded higher pod yield than 0.60 IW/CPE ratio. Moisture stress during pod formation and maturity phase will be at the expense of pod yield. Higher pod yield (2638 kg ha⁻¹) in peanut during kharif season was recorded when irrigation at 0.40 IW/CPE ratio at the pod developing and pod formation stages. For rabi season (Anon, 1980), irrigation at 0.60, IW/CPE ratio during the early growth phase and 0.80 IW/CPE ratio at peg development pod formation stages found to record higher pod yield of 2060 kg ha⁻¹. Jayabal et al. (1981) found that in sandy clay loam soil, irrigating peanut (TMV.7) at 0.50 IW/CPE ratio during early growth and flowering phases and 0.70 ratio thereafter was the best for getting higher yield. Peanut needed wider irrigation interval of 17 to 18 days (0.40 IW/CPE ratio) through 0.80 IW/CPE ratio during pegging and maturity phases for higher pod yield. In rabi season, no difference among different levels of irrigation regimes was observed (Anon, 1984). The maximum pod yield can be obtained, provided irrigation at 0.40 ratio during podging and maturity. Dhonde et al. (1985) observed that scheduling of irrigation either at 0.60 or 0.90 IW/CPE ratio throughout the growth produced more pod yield over 0.40 IW/CPE ratio in peanut. Ravikumar et al. (1987) further confirmed the result and were of the opinion that irrigation at 0.65 IW/CPE ratio during early stages and irrigation at 0.80 during reproductive stages increased the pod yield of peanut. Chaven et al. (1988) recorded an average pod yield of 1.32, 1.62, 1.88 and 1.74 t ha⁻¹ under 0.40, 0.60, 0.80 and 1.00 IW/CPE ratios respectively. However, irrigation at 1.20 IW/CPE ratio for peanut registered higher pod yield of 3.26 t ha⁻¹ as against 0.60 and 0.90 IW/CPE ratios (Katre et al. 1988). Thanzuala and Dahiphale (1988) confirmed the earlier reports of Katre et al. (1988) and opined that higher pod yield was in direct correlation with frequency of irrigation. They registered a maximum yield of 2.38 t ha⁻¹ with irrigation at 0.80 IW/CPE ratio as against 0.60 IW/CPE ratio. Jadhav et al. (1989) advised to irrigate summer peanut at 0.60 IW/CPE ratio which requires eight irrigations including three common irrigations at early stages. For Rabi season peanut, Kadam and Patil (1992)
recommended an irrigation scheduling at 1.00 IW /CPE ratio than 0.75 or 0.50 IW /CPE ratios. Sabale and Khuspe (1989) observed that the root nodules per plant; fresh pods and haulm yields were higher when peanut crop was irrigated at 80-85 per cent available soil moisture. Khade et.al. (1989) concluded that an increased pod yield could be obtained when peanut was irrigated at 60 mm cumulative pan evaporation. From the comparative study of irrigation during the critical growth stages, every ten days interval and at 0.75 IW /CPE ratio, Thanzuala and Dahiphale (1989) concluded that the pod yields were more effectively increased with irrigation based on IW /CPE ratio. The regression analysis predicted the dry pod yield of 2.93 t ha\(^{-1}\) with 125 cm depth. Intermediary irrigation levels of 0.70 and 0.90 IW /CPE ratios, as quoted by Desai et.al. (1989) were better than irrigation at 0.50 and 1.10 IW /CPE ratios.

According to Mahakulkar et.al., (1990) cumulative pan evaporation (CPE) of 75 mm was reported to be better index to schedule irrigation of peanut. CPE of 50 and 100 mm produced comparatively lower pod yields. Rajagopal and Palchamy (1990) obtained a dry pod yield of 4240 kg ha\(^{-1}\) when peanut crop was irrigated at 0.75 IW /CPE ratio. Irrigation at lower or higher regimes resulted in lower yields. Pawar et.al. (1991) opined that irrigation at 50 per cent depletion of available soil moisture at 75 mm CPE recorded higher yields than when compared to irrigating every ten days from the seedling stage. Kachroo and Walia (1991) shared the same view for monsoon season peanut on sandy loam soils, Satapathy and Patro (1992) suggested that irrigation at 0.50 or at 0.75 IW /CPE ratio make not much difference on the pod yield of peanut. Irrigation at longer intervals (0.50 IW /CP ratio) during the vegetative phase and irrigation at shorter intervals (0.75 IW /CPE ratio) during reproductive phase was found better than an uniform irrigation of shorter or longer interval (Ramachandrappa et.al., 1992). Irrigation schedule at 80 mm CPE from 10 to 40 days after sowing (DAS) and later at 53.3 mm CPE registered higher pod yield of peanut. This clearly indicated, as concluded by Ramachandrappa et.al. (1992), that stress during 10 to 40 DAS was beneficial in getting higher pod yield. The pod yield of irrigated peanut can be increased by irrigating at 0.80 IW /CPE ratio (Padma and Rao, 1992) or irrigation at CPE of 100 mm (Bhoi et.al. 1993) under irrigation level of 0.60 IW /CPE ratio along with straw mulch @ 10 to ha\(^{-1}\) (Ghorai, 1994). Khade et.al. (1994) opined that peanut planted in medium black soil conditions of Konkan region of Maharashtra on broad beds and furrows and irrigated at 1.00 IW /CPE ratio produced higher dry pod yield of 3.1 t/ha.

5.2.3 Irrigation on Yield attributes:

Keeping the total quantity of irrigation water almost constant, high frequency irrigation registered maximum pod yield due to higher number of filled pods per plant, weight of pods and 100 kernel weight than higher quantity with lower frequency of irrigation (Ramireddy et.al. 1980). Except shelling percentage, all other yield attributes like Filled pods per plant, total pods per plant and their weight increased on order of irrigation at 1.20, 0.90 and 0.60 IW /CPE ratios corroborating with the pod yield (Katre et.al. 1988). The test weight and shelling percentage of peanut was found to increase under higher frequency of irrigation (Thanzuala and Dahiphale, 1988). The number and weight of pods per plant was found to increase at lower number of irrigations. The advantage of pre-flowering stress in peanut was earlier reported by Nageswara Rao et.al. (1988) and Dayal (1989). Pre-flowering stress in peanut and release of it during the reproductive stage result in greater pod synchrony, production of more...
matured pod and Kernel weight per plant (Ramachandrappa et.al. 1992 and Naveen et.al. 1992). Ramachandrappa et.al. (1993) suggested an irrigation schedule of 0.50, 0.75 and 0.75 IW /CPE during early, flowering and maturity stages, respectively. This resulted in higher number of matured pods and lower number of immatured pods per plant.

5.2.4 Irrigation scheduling on water use efficiency: In general, oil seeds are efficient in water use and therefore require less water for their growth (Hukkeri and Pandey, 1977). Field water use efficiency (WUE) was maintained same under 0.60 and 0.90 IW /CPE ratios but decreased slightly under 1.20 IW /CPE ratio (Katre et.al. 1988). Chaven et.al. (1988) concluded that WUE decreased with increase in irrigation frequency. Similar report was documented by Katre et.al. (1988) and also of the view that intermediary irrigation levels increased the WUE. Among the irrigation schedules of 1.00, 0.75 and 0.50 IW /CPE ratios, 0.75 ratio performed better to record higher WUE of 4.62 kg ha⁻¹ mm⁻¹. Khade et.al. (1989) opined that increased WUE could be achieved through decreased consumptive use. Similar results were reported by Desai et.al. (1989); Jadhav et.al. (1989); and Shinde et.al. (1994).

5.2.5 Irrigation scheduling on oil content: The oil and protein content of peanut grown under 0.65, 0.80 and 0.95 IW /CPE ratios applied during the growth stages were found higher (Kumar et.al. 1987). Parameswaran and Bhalani (1991) concluded that the total oil content tended to be low either when water was withheld or given in excess especially at pod filling and pod maturity stages. Seed oil content in the irrigated peanut was found to be higher than in the rainfed peanut (Padma and Rao, 1992). Significant interaction between the oil content, oil yield and irrigation scheduling based on IW /CPE ratio was reported by Desai et.al. (1989).

5.2.6 Irrigation scheduling on physiological parameters: An understanding of response of crop foliage to changes in the amount and status of soil water in the root zone is far from complete. The status of water in the plants represent an integration of atmospheric demand, soil water potential, rooting density and distribution as well as other plant characteristics (Kramer, 1969). The most promising measurements reported to be useful under field conditions include stomatal resistance (Pallas et.al. 1970) and canopy temperature (Sanders et.al. 1982). Canopy temperature can be used as an indicator of crop water status (Jakson, 1982) and it increased with drought (Sanders et.al. 1982). The afternoon canopy temperature under irrigated conditions, as reported by Sanders et.al. (1982), was 28.5°C while it was 35°C in drought. In peanut, the leaf air temperature was generally at or below zero indicating that the leaf was cooler than air (Bennett et.al. 1984). But, any decrease in moisture supply will increase the canopy temperature considerably (Misra and Gangwar, 1987). Powell et.al. (1987) used maximum and minimum air temperature for scheduling irrigation for peanut. Canopy temperature must be measured daily at solar noon and Schubert and Sanders (1987) concluded that it was above ambient temperature when plants were assumed to be water stressed. This ambient temperature of canopy can be better utilized for irrigation scheduling. The water potential of plant tissue has become standard means of expressing plant water status. Studies conducted by Patel et.al. (1983) showed that the leaf water potential decreased from (-) 1.0 to (-) 3.8 Mpa with increase in drought. The frequent irrigation however increased the water potential and stayed at around (-) 1.2 to (-) 1.3 Mpa. Studies of Stirling et.al. (1989) revealed that irrigation at late growth stages comparatively lost turgor in leaves around midday than that of the early irrigated plants.
This early season moisture deficit reduced leaf area expansion and turgor although the rate recovered during irrigation and concluded that the relative leaf water content was greatly affected by evaporative demand, and the peak threshold occurred during flowering and pod formation stage of peanut. Transpiration rates of field peanut increases gradually up to 14.00 hrs and afterwards start decreasing. Kanber et al. (1989) used to calculate the amount of irrigation and dates and intervals using the evapotranspiration values and found a strong linear relationship with yield.

**CONCLUSIONS**

Groundnut is the major oilseeds crop accounting for 45 percent of oilseeds area and 55 percent of oilseeds production of the country. As such this crop has to play a major role in bridging the vegetable oil gap in the country. But the current average yield level is very low as compared to what is being obtained in most of the groundnut growing other countries. In India, the reasons for low peanut yield are the use of low yield potential varieties, maintenance of inadequate plant population, poor soil fertility and water management. Peanut perform better in terms of yield and quality when good cultivar sown under optimum plant density coupled with efficient nutrient and water management. Groundnut being a leguminous crop, it is capable of fixing atmospheric nitrogen. Application of fertilizer including gypsum in adequate quantities become more essential for obtaining higher yields. Adoption of an improved variety alone can increase the yield by about 20 per cent. Hence a proper understanding of management practices viz., season, suitable varieties; optimum plant density, efficient nutrient and water management are necessary to enhance the productivity of peanut which in turn helps our country to avoid shortage of edible oils and large scale imports at the expense of huge foreign exchange.

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