5. DISCUSSION

The production of economic yield in a crop is dependent on the following three phases:

1. Stand of the crop, initiation, and development of organs for nutrient absorption and photosynthesis.
2. Initiation and development of floral organs and sinks.
3. Production, accumulation, and translocation of metabolites into sinks.

The effects of varying nutrient levels and water supply and changes in light and temperature conditions on the above aspects help in understanding the factors affecting yield. The knowledge, thus gained can be used to increase production.

Field experiments were carried out during 1966 kharif season and 1967 summer season on Spanish Improved groundnut to study the effect of different soil moisture regimes and levels of nitrogen and phosphorus on growth, yield, and quality. The consumptive use of water in various soil moisture regimes was studied and correlated with that of sunken screen evaporimeter and tensiometer.
for scheduling irrigation. The results obtained are discussed below:

5.1 Effect of soil moisture on growth, yield, and quality of groundnut:

Plant growth is greatly dependent on rate of production and accumulation of dry matter. The production of dry matter in turn depends on the formation of organs for nutrient absorption and photosynthesis. Adequate supply of moisture in the root zone influences the root development.

The increase in root spread and in weight to the extent of 60 per cent of the total was during 30-60 days period of growth. The maximum root spread of 690 cm² was obtained with irrigation at 100-50 per cent available soil moisture. In treatment receiving irrigation at 100-75 per cent available soil moisture, reduction in area as well as development of roots was found. This may be well due to excess of soil moisture which might have affected aeration and consequently the rate of uptake of solutes from soil. This is in conformity with the work of Maximov (1928) who reported such unfavourable influence on root growth due to excess of soil moisture.

The weight and spread of roots in treatment receiving irrigation at 100-25 per cent available soil moisture were
least. The weight decreased in both seasons as compared with that of moisture regime receiving irrigation at 100-75 per cent available soil moisture. This might be due to water stress. Similar is the finding of Kramer (1969) who found that moisture stress in wheat decreased root growth which in turn affected plant growth and development. Greenway et al. (1968) reported that low water potential decreased uptake of nutrients and reduced number of roots in excised plants.

The root weight of plants with irrigation at 100-50 per cent available moisture, was maximum in both seasons. This might be because of better aeration conducive to root growth. Albert and Armstrong (1931), Loehwing (1931), Weaver and Himmel (1950) and Dean (1933) have found that root growth of plants was more vigorous and they were much branched and fibrous under aerated and adequate moisture conditions of soil.

Roots produced by plant were more in summer than in kharif. The high temperature, intensity of radiant energy and the longer hours of sunlight in summer might have contributed towards increase in photosynthesis and this in turn might have favoured the plants to absorb more solutes from soil and supply more metabolites for root development. Such effects have been reported by Hagan (1952).
who reviewed the work on soil temperature and plant growth.

The yield in crops is primarily dependent on dry matter production. The dry matter accumulation was highest amounting to 60 per cent of the total during 30-60 days period of growth. This coincided with the period of maximum root production. The daily rate of growth was maximum i.e., 142 mg in kharif and 167 mg in summer per plant in moisture regime irrigating at 100-75 per cent available moisture. This might have occurred because of more absorption of soil moisture and nutrients. The daily rate of dry matter accumulation per plant in the same period was 113 mg in kharif and 125 mg in summer (Table 19), in moisture regime irrigating at 100-25 per cent available soil moisture. The moisture stress due to longer irrigation interval in moisture regime 100-25 per cent available moisture and in the treatment where no irrigation was given kharif, caused reduction in root growth, and this might have affected carbon dioxide intake due to increased stomatal resistance on account of stress. These in turn might have decreased the net photosynthetic activity and plant growth. Such reduction in photosynthesis was observed in cotton by Troughton (1969) with increasing water stress and this was attributed to stomatal closure.

The dry matter produced per plant in summer was more by about 60 per cent than in kharif. In summer the effect
of higher temperature and the longer day light and the higher light intensity, might have caused higher rates of photosynthesis, resulting in greater biological production and higher amounts of accumulation of dry matter. Hagan (1952) reported that the net synthesis of organic compounds depended on the rate of carbon assimilation and respiration controlled by temperature. Miller and Duley (1925) observed that wheat and soyabean plants subjected to maximum length of light period had greatest amount of dry matter. Cheliadizpra (1941) studying the response of groundnut to day length found that longer day increased green weight.

In the treatment receiving irrigation at 100-50 per cent available soil moisture where irrigation was optimal the soil aeration and the soil moisture were probably adequate. The daily nitrogen and phosphorus absorption per plant (Tables 19 to 22) was maximum in all stages of crop in this treatment. The daily rates of absorption of nitrogen and phosphorus were the highest during the 30-60 days period of growth of crop both in kharif and summer. The moisture regimes irrigating at 100-25 per cent available moisture in summer and receiving no irrigation in kharif recorded the least absorption of nitrogen and phosphorus.
The maximum uptake per plant was recorded in moisture regime irrigating at 100-50 per cent available soil moisture which might have provided throughout the growth of crop, favourable conditions like optimum moisture with adequate aeration for extensive root development. While in moisture regime, irrigating at 100-75 per cent available soil moisture, the uptake of nutrients decreased probably on account of lesser root development and availability of nutrients under poorly aerated conditions of soil. In case of moisture regime irrigating at 100-25 per cent available soil moisture in summer and no irrigation regime in kharif the lower uptake of nutrient was probably on account of reduction in root development. This is in accordance with Miller (1938) who reported that the amounts of solutes accumulated in plants is closely related to the rate of aerobic respiration of roots and microbial activity. Shetti (1966) working on root aeration in groundnut observed that providing aeration to groundnut by addition of organic matter or sand at fruiting zone in medium black soil increased shelling percentage as well as kernel weight.

Optimal soil moisture regime thus has an important and far reaching effect, in that it influences root growth which in turn causes greater absorption of nutrients and ultimately resulting in biological productivity.
Flower production is dependent on the size of the plant, moisture supply, and environment factors like temperature and light at flowering stage.

In the moisture regimes, no irrigation in kharif and irrigating at 100-25 per cent available soil moisture in summer, there was maximum production of 48.2 and 75.1 flowers per plant, respectively. One of the effects of moisture stress on plants is hastening of senescence, resulting in early and profuse flowering - but not necessarily resulting in fruits. However, the irrigation regime, irrigating at 100-50 per cent available soil moisture, recorded highest reproductive efficiency of 19.2 and 21.4 in kharif and summer, respectively. The plants in 100-50 per cent available moisture regime produced higher dry matter production with highest nutrient accumulation. These two coupled with adequate moisture supply at flowering favoured highest reproductive efficiency. Such effects have been reported in wheat by Chinoy (1962) and by Bingham (1967) and in corn by Denmead and Shaw (1960). Therefore, to obtain maximum productive efficiency, supply of adequate soil moisture to the plant is essential during flowering and gynophore stages.

The flower production was more by about 40 per cent in summer. In flower production, sunshine and hormone play
an important role in addition to nutrient and soil moisture supply. In summer the average number of sunshine hours per day was 9.10 as against 3.37 hours in kharif at flowering stage. This means that the plants in summer were illuminated for more than double the time in kharif, which might have influenced the flower production. This is in accordance with the work of Cheliadinora (1941) who reported that peanut bloomed abundantly when illuminated for a longer time.

Maximum yield is obtained when optimum water status is maintained at different stages of the crop growth. The effect of water stress in three important stages which determine the growth and development, the pod formation and crop yield, are:

1. Floral initiation and flower development – flowering
2. Anthesis and fertilization – gynophore
3. Pod development

A main factor for increased yield in crops is the presentation of the maximum possible plant surface for photosynthesis. This means the exploitation of the dry matter accumulation potential of the crop as compatible with development of the crop. Thus the factors for pod
yield in groundnut are:

1. Dry matter accumulation
2. Nutrient uptake
3. Reproductive efficiency
4. Adequate supply of moisture and aeration at fruiting zone

In groundnut an upper limit for kernel growth is imposed by the size of shells. This physical ability for pod yield which can be broken down into following three components:

Capacity for yield container = Number of pods per plant × Number of pods-double and single kernelled per plant × weight of 100 kernels

This physical capacity for yield container in moisture regime receiving irrigation at 100-50 per cent available soil moisture was maximum. Because the extensive root system facilitated in greater nutrient uptake and larger dry matter production resulting into highest reproductive efficiency and economic yield.

While plants in moisture regime irrigating at 100-25 per cent available soil moisture suffered from moderate moisture stress in different stages of growth due to prolonged intervals in irrigation. So the capacity for yield container was lowered. The plants in moisture regime
receiving no irrigation in kharif suffered from severe stress during the growth. The moisture stress reduced considerably the three components of the yield container on account of their direct adverse effect on photosynthesis and hastened maturity. This is in agreement with the work of Wardlaw (1967) who has shown conclusively that water stress reduced photosynthesis, hastened maturity and contributed to lower grain weight in wheat.

Pod filling and development is a relatively rapid process and is influenced by both pre-flowering and post-flowering conditions of the plants. In case of groundnut, the post-flowering stage is the most important. The pod development requires accumulation of photosynthates in leaves and gynophores. In this crop, most of the increase in plant weight as well in uptake was after anthesis in a period covering from 30 to 60 days. The reduced photosynthesis at any time of the post-anthesis stage might have adverse effect on pod yield.

Another important aspect of economic yield is the translocation of metabolites into the developing pods. This is generally reflected in the number of filled and unfilled pods. Number of undeveloped pods in kharif and weight of such pods in summer were highest (Tables 31 (a) and (b) ) in treatment receiving no irrigation in kharif
and in treatment receiving irrigation at 100-25 per cent available moisture in summer, respectively. This shows that the moisture stress increased the number and weight of undeveloped pods. A decrease in the amounts of translocation of metabolites in treatments where inadequate moisture was there is quite evident. Similar observations on the effect of moisture stress during bloom period to grain development in increasing the number and weight of undeveloped grains in snap bean, wheat, and barley have been made by Miller and Gardner (1972), Wardlaw (1967) and Aspinall (1965).

In both seasons, the pod yields in moisture regime irrigating at 100-50 per cent available soil moisture were highest due to the greatest quantities of biological yield, better translocation of metabolites to the pod from leaves, resulting in highest weight of 100 kernel (Tables 34 and 35) and thus maximum yield. The causes for low yield in moisture regime irrigating at 100-75 per cent available soil moisture might be due to decreased mineral uptake (Tables 47 and 51) in gynophore stage and lesser quantities of biological yield and lesser translocation of photosynthates to pods from leaves. The least yield recorded was in moisture regime receiving no irrigation in kharif as it suffered from severe moisture stress during flowering.
and pod development stages. This is in agreement with the findings of Su and Lu (1963) who worked on peanut and found that medium moisture gave maximum yield. Chandra Mohan (1970) studying the efficient water management for groundnut has shown that maximum yield of 3221 kg per hectare was obtained when the crop was irrigated at 60 per cent moisture availability in 30 cm soil depth.

Yield of pods was more by about 25 per cent in summer than in kharif. This may be because plants were illuminated for a longer period in summer than in kharif i.e., for 1021.2 hours in summer and 520.1 hours in kharif and higher mean monthly temperature range of 34.1 to 36.0°C prevailed in summer as against the mean monthly temperature range of 26.4 to 27.6°C in the kharif in the gynophore and pod development stages. These two environmental factors might have induced the plants to produce greater quantities of dry matter, and translocation of larger quantities of photosynthates to yield contents of the pods and thus increased the yield.

Harvest index is a useful parameter to assess the translocation efficiency. Highest harvest index was obtained in kharif in treatment receiving irrigation at 100-50 per cent available moisture. The harvest index in treatment receiving irrigation at 100-75 per cent available soil moisture was on par with that of treatment
receiving irrigation at 100-25 per cent available soil moisture. The lowest harvest index was recorded in treatment receiving no irrigation in kharif.

The highest harvest index was in the treatment when irrigation was provided at 100-50 per cent available moisture during both kharif and summer (Tables 62 and 63). Since harvest index is an assessment of the extent of partitioning of dry matter between reproductive and vegetative parts, it is obvious that under conditions of adequate moisture there is also a better translocation of metabolites into pods and thus better development. This is further seen in the number of two seeded pods per plant, shelling percentage and kernel weight, all of which were higher in the treatment receiving irrigation at 100-50 per cent available soil moisture contributing to high yields.

The harvest index was about 4 per cent higher in kharif than in summer. The crop took 100 days in kharif and 116 days in summer for maturity. On account of higher temperature and day length (Appendix I (b)) in summer the crop produced large leaf and stem structure (Tables 17 and 18) in relation to pod yield resulting in imbalance of time for vegetative growth and pod filling. Such influence in time for vegetative growth and grain filling in cereals has been reported by Donald (1962) and Wallace and Munger (1966).
The shelling percentage, 100 kernel weight and oil percentage in kernel recorded in moisture regime irrigating at 100-50 per cent available moisture were slightly higher reflecting the greater translocation of metabolites into pods under proper moisture conditions. In the moisture regime irrigating at 100-75 per cent available moisture, least shelling percentage, 100 kernel weight, and oil per cent were recorded in both seasons. Such effects are reported by Singh et al. (1968) that the higher irrigation levels did not influence the shelling out turn and oil percentage.

Oil percentage in kernel was more by about 1.5 to 2.0 in summer than in kharif. This might be due to more synthesis of metabolites on account of higher temperature (36°C) and longer hours of sunshine prevailed in summer than in kharif (27.6°C) in pod development stage.

5.2 Effect of fertilizer levels on growth, yield, and quality of groundnut:

Low or high moisture condition and high osmotic concentration cause injury to the germinating seeds. In the present study application of nitrogen at 25 kg & 50 kg per hectare had depressing effect on germination. It reduced the germination by about 2 to 5 per cent in kharif and 2 to 4 per cent in summer. This decrease in germination is presumably due to fertilizer applied by the side of the
seed at planting. Patil (1953) tried heavy dressing of nitrogenous fertilizer in the rows, at planting on sorghum, in fine sandy loam. He reported that high rate of nitrogenous fertilizer application may increase the salt concentration in the soil moisture and in turn osmotic pressure affecting the germination of seeds. Ballard and Petrie (1936) and Petrie (1943) noted an initial depression in germination in case of sudan grass and wheat with the application of nitrogenous fertilizers. They stated that the intake of considerable amount of ammonium ion released during mineralisation may cause toxic alkalinity in the sap of roots which might decrease the rate of water absorption. Yandgoudar (1966) studied the effect of nitrogenous fertilizers on germination of groundnut and found that nitrogenous fertilizer caused more injury than phosphatic fertilizer.

An important agronomic manipulation which influences crop growth, and yield is an adequate application of plant nutrients through fertilizers. Plant nutrients influence the growth, through their effect on leaf area, the colour of the foliage, chlorophyll content, chemical composition and reproductive development. High yields can be obtained first by building of an efficient photosynthetic system. In this regard attainment of leaf area for maximum dry matter
production per unit area is the key for a high economic yield. The attainment of the optimum leaf depends upon the roots system which can absorb the nutrients for required growth.

In the present study the weight of roots recorded per plant at harvest increased significantly with increase in levels of phosphorus in both seasons, (Tables 23 and 24). The fertilizer treatment receiving 25 kg nitrogen and 150 kg $P_2O_5$ per hectare recorded maximum root weight per plant at maturity in kharif and summer. The other growth attributes like number of leaves, dry matter accumulation were higher in treatment receiving application of 25 kg nitrogen and 150 kg $P_2O_5$ per hectare. When growth and development of whole plant are considered, there are always correlative growth phenomena. The roots supply adequate plant nutrients to the aerial parts which in turn provide metabolites for root growth. The growth of these are interdependent. Increase in the level of phosphorus increased root growth. A combination of 25 kg nitrogen per hectare with 150 kg $P_2O_5$ per hectare was most suitable. However, increasing the level of nitrogen from 25 to 50 kg per hectare did not further enhance root growth showing the greater importance of phosphorus in root development.
The roots produced per plant in summer were more by about 15 per cent than in kharif. This is again due to the favourable environmental factors causing more photosynthetic activity resulting in more metabolites for development of roots. Roots being one of the major sinks in the developmental process of a plant, it is able to attract metabolite flow and thus directly affect the photosynthetic efficiency.

The dry matter production in different stages of crop increased with the increase in the levels of nitrogen and phosphorus, in both the seasons. Application of adequate quantities of fertilizers and their uptake by the plants, resulted in higher contents of nitrogen and phosphorus (Tables 46 to 53) in all stages of the crop. Such relationship has been found by Leopold (1934) and Sestack (1966) in field plants and in cabbage, respectively. The accumulation of dry matter was not only rapid but also it was about 60 per cent of the total dry matter in gynophore stage (30-60 days) when the growth and assimilation rates were maximum. The gynophore stage (30-60 days after germination) appeared to be the most critical stage. During this stage the maximum uptake of nutrients and maximum accumulation of dry matter occurred. Similar results have been reported by Olson and Bledsoe (1942) who worked on
chemical composition of the cotton plant and the uptake of nutrients at different stages of growth. They concluded that greatest percentage of dry matter was from flowering to early boll formation and it was also the period of greatest nutrient uptake. The dry matter accumulation at maturity was least i.e., 3.51 g in kharif and 6.38 g in summer per plant in treatment receiving no fertilizer. These findings corroborate with the work of Black (1965) who worked on crop yields in relation to soil fertility and reported that the dry matter accumulation increased as the fertility of soil increased and provided for greater photosynthetic activity.

In groundnut, adequate nutrition level at pre-flowering induces more production of flowers as well higher productive efficiency. In the present study treatment receiving application of 50 kg nitrogen and 150 kg P₂O₅ per hectare produced maximum flowers of 49.7 in kharif and 76.6 in summer per plant as against 46.9 in kharif and 74.0 in summer per plant in treatment receiving 25 kg nitrogen and 150 kg P₂O₅ per hectare (Table 26). But the percentage of setting of flowers into good pods was 18.6 in kharif and 20.3 in summer in treatment receiving 50 kg nitrogen and 150 kg P₂O₅ per hectare as against maximum setting percentage of 19.5 in kharif and 21.3 in summer in treatment receiving
25 kg nitrogen and 150 kg $P_2O_5$ per hectare (Table 27). This might have occurred for two reasons - inhibition of flowers after fertilization and imbalance of nutrition or deficiency of phosphorus. Among nitrogen levels, low nitrogen rate produced higher percentage of flower forming pegs. Low nitrogen level produced less flowers per plant. Such inhibition of flowers has been observed by Fortainer (1957), Reid (1956) and Smith (1954) in groundnut. The imbalance of nitrogen and phosphorus can be known if their accumulation in plant at gynophore stage is studied. At this stage percentage of nitrogen in the plant was 2.48 in kharif and 2.85 in summer in fertilizer treatment receiving 50 kg nitrogen and 150 kg $P_2O_5$ per hectare as against 2.33 in kharif and 2.66 in summer in treatment receiving 25 kg nitrogen and 150 kg $P_2O_5$ per hectare (Table 39) while with phosphorus percentage in the plant was 0.39 in kharif and 0.43 in summer in treatment receiving 50 kg nitrogen and 150 kg $P_2O_5$ per hectare (Table 43) as against 0.32 in kharif and 0.40 in summer in treatment receiving 25 kg nitrogen and 150 kg $P_2O_5$ per hectare. This shows that accumulation of nitrogen was more in plants receiving 50 kg nitrogen and 150 kg $P_2O_5$ per hectare. This nutritional imbalance or deficiency of phosphorus might be responsible for lower reproductive efficiency in treatment receiving 50 kg nitrogen.
and 150 kg $P_2O_5$ per hectare inspite of the maximum dry matter accumulation and flower production. This conforms with the work of Bledsoe and Harris (1950) who worked on the influence of mineral deficiency on vegetative, flower and fruit production of groundnut and reported that groundnut plants produced few fruits when they were deficient in phosphorus. Wahhab and Mohammad (1958) working with phosphorus fertilization of peanut grown in sandy loam found that 30 pounds of nitrogen stimulated vegetative growth and tended to decrease the beneficial effect of phosphorus. These percentages of nitrogen and phosphorus in treatment receiving 25 kg nitrogen and 150 kg $P_2O_5$ per hectare were found to be optimum for getting higher reproductive efficiency. These findings are in confirmity with those of Nicholasd and Cox (1976) who found that concentration of 2.50 per cent nitrogen and of 0.38 per cent phosphorus in Virginia plants of groundnut at seventh week of growth resulted in maximum reproductive development.

The number of undeveloped pods in kharif (Table 31 (a)) and the weight of undeveloped pods in summer (Table 31 (b)) increased with higher level of nitrogen and decreased with increase in level of phosphorus. The differences in number of undeveloped pods and in weight of such pods was more
pronounced in treatment where more nitrogen and less phosphorus were given. The maximum number of undeveloped pods per plant in kharif was 4.63 and that of weight was 106.13 g in treatment receiving 50 kg nitrogen and 50 kg P$_2$O$_5$ per hectare. The minimum number of undeveloped pods per plant was 3.05 in kharif and that of weight was 71.25 g per plot in summer in treatment receiving application of 25 kg nitrogen and 150 kg P$_2$O$_5$ per hectare.

This can very well be explained if the absorption rates of nitrogen and phosphorus in gynophore stage are studied. At gynophore stage the rate of absorption of nitrogen in mg per day was 0.142 and 0.183 in kharif and 0.152 and 0.207 in summer (Table 47) in treatment receiving application of 25 kg and 50 kg nitrogen, respectively, with 150 kg P$_2$O$_5$ per hectare as against the absorption of phosphorus rate of 0.019 and 0.028 in kharif and 0.023 and 0.031 in summer (Table 51). This shows that there was more absorption of nitrogen in treatment receiving 50 kg nitrogen and 150 kg P$_2$O$_5$ and this might have resulted in more undeveloped pods in treatment receiving higher level of nitrogen. This is in conformity with findings of Gopalakrishna and Nagarajan (1958) who observed that phosphorus was a limiting factor in yield, and its deficiency
reduced flower production as well as the size of the pods. Satyanarayan and Krishna Rao (1962) who observed that 20 kg nitrogen and 40 kg P$_2$O$_5$ per hectare increased the number of two-seeded pods per plant. So, the application of fertilizers in proper proportion will lead to proper development of plants with a capacity for high yield.

The filling of pods depends largely upon the dry matter accumulation and nutrient status of pre-flowering and post-flowering conditions of the plant. In case of groundnut, the post-flowering stage is the most important as the major portion of dry matter and uptake of mineral nutrients are accumulated in post-flowering stage of 30 to 60 days of crop, and this might affect the yield components like two-seeded pods per plant, shelling percentage, and 100-kernel weight. The yield of groundnut increased with the increase in fertilizer levels in both seasons (Tables 60 and 61). The highest yield of 2910.50 kg per hectare in kharif and 3632.88 kg per hectare in summer in treatment receiving 25 kg nitrogen and 150 kg P$_2$O$_5$ application per hectare was obtained. This is due to the greater capacity for yield container and for the filling of container with synthates from leaves and stems to the pods. In treatment receiving no fertilizers, the capacity for pod yield container was lowest as the filling capacity of the container with synthates from leaves and stems was minimum.
on account of lowest dry matter accumulation and uptake of nutrients due to inadequate supply of nutrients during the growth. Similar work has been reported by Asana (1966) who demonstrated that increase in dry weight in wheat after anthesis is associated with grain filling.

The maximum harvest index was 57.62 and 52.31 in treatment receiving application of 25 kg nitrogen and 150 kg P₂O₅ per hectare in kharif and summer, respectively, followed by the treatment receiving 25 kg nitrogen and 100 kg P₂O₅ per hectare. The least was 50.62 in kharif and 49.18 in summer in treatment receiving application of 50 kg nitrogen and 50 kg P₂O₅ per hectare (Tables 62 and 63). The percentage of nitrogen and phosphorus per plant in treatment receiving application of 50 kg nitrogen and 50 kg P₂O₅ per hectare in gynophore stage was 2.37 and 2.69 and 0.33 and 0.41 during kharif and summer season, respectively, as against 2.33 and 2.66 and 0.32 and 0.40 (Tables 39 and 43) in treatment receiving application of 25 kg nitrogen and 150 kg P₂O₅ per hectare. This means that plants were at higher nutrition level of phosphorus than that of plants receiving application of 50 kg nitrogen and 150 kg P₂O₅ per hectare and as such amounted to imbalance in nutrition, resulting in more undeveloped pods and reduction in yield and harvest index. This is in
confirmity with findings of Gopalkrishna and Nagarajan (1958) who reported that phosphorus deficiency affected size and filling of pods resulting in decrease in yield and harvest index.

The mineral composition in the kernel is greatly influenced by the nutrient status of the plant and the dry matter accumulation in plant at flowering and post-flowering gynophore stages. In the present study the kernels from treatment receiving 50 kg nitrogen and 150 kg P₂O₅ per hectare contained highest percentage of nitrogen i.e., 3.93 and 4.21 and highest percentage of phosphorus i.e., 0.42 and 0.48 (Tables 41 and 45) in kharif and summer, respectively. This is due to the translocation of greater quantities of synthates from leaves and stems to the yield container i.e., pods, as plants in treatment receiving 50 kg nitrogen and 150 kg P₂O₅ produced maximum dry matter and accumulated greatest quantities of nutrients. Satyanarayan and Krishna Rao (1962) studied the mineral nutrition in groundnut and stated that the mineral composition of kernel increased with the increase in levels of nitrogen and phosphatic fertilizers.
Synthesis of oil requires energy in the form of high energy phosphate, just as any other metabolic process. In this study, the oil content increased as the levels of phosphatic fertilizer increased. The maximum oil percentage recorded was 55.02 in kharif and 55.66 in summer (Tables 36 and 37) in treatment receiving 25 kg nitrogen and 150 kg P$_2$O$_5$ per hectare. The percentage of oil was least in the treatment which did not receive any fertilizers in both seasons. This is in accordance with the finding of Satyanarayan and Krishna Rao who studied the nutrition of Spanish Improved groundnut and indicated that the application of 40 pounds of phosphorus per acre at sowing influenced the oil content. Venema (1962) reported that fertilizer containing sulphate anion increased the oil content of oilseeds.

5.3 Combined effect of soil moisture and nutrient supply on growth, yield, and quality of groundnut:

In the present study the root weight increased within each moisture regime as phosphatic fertilizer levels increased. The highest weight of root recorded was 0.49 g and 0.54 g per plant (Tables 23 and 24) in moisture regime receiving irrigation at 100-50 per cent available soil moisture, combined with 25 kg nitrogen and 150 kg P$_2$O$_5$ per hectare in kharif and summer, respectively. In moisture
regime receiving irrigation at 100-25 per cent available moisture, the roots might have suffered from inadequate supply of nutrients due to drying of soil. The crop might have suffered from severe moisture stresses in moisture regime receiving no irrigation in kharif. In case of moisture regime receiving irrigation at 100-75 per cent available moisture, the roots might have suffered from lack of adequate nutrients on account of poor aeration and reduced microbial activity.

The extensive root system in 100-50 per cent available moisture regime with adequate supply of moisture and nutrients resulted in greater dry matter production and uptake of nitrogen and phosphorus. The dry matter accumulation tended to increase with increase in levels of fertilizers within same moisture regime (Tables 17 and 18). The moisture regime receiving irrigation at 100-75 per cent available moisture combined with 50 kg nitrogen and 150 kg $P_2O_5$ per hectare recorded higher dry matter production of 7.06 g in kharif and 12.66 g per plant in summer. The dry matter production decreased in 100-25 per cent available soil moisture regime in kharif. This might be due to reduction in root spread and weight resulting in lesser absorption of nutrients and photosynthesis and consequently on number of undeveloped pods per plant in kharif and their
weight per plot in summer (Tables 31 (a) and (b)). The lowest number of 1.62 undeveloped pods per plant in kharif and 57.20 g of undeveloped pods in summer were recorded to moisture regime receiving irrigation at 100-50 per cent available moisture with 25 kg nitrogen + 150 kg P₂O₅ per hectare. This happened on account of adequate supply of moisture, aeration, and nutrients to the plants throughout the growth period and as such the daily absorption rates of nitrogen and phosphorus were highest (Tables 19 to 22) resulting in greater quantity of synthates and yield.

Highest number of undeveloped pods in kharif and weight of undeveloped pods in summer were recorded in moisture regime receiving no irrigation in kharif and moisture regime receiving irrigation at 100-25 per cent available moisture in summer combined with higher nitrogen level probably because of moisture deficits and imbalance in nutrition. This is in accordance with work of Trumble (1947) who concluded that the phosphorus content in plants was relatively low due to inadequate soil moisture. Pate (1931) who indicated that sufficient phosphorus in plants decreased the number of unfilled pods. While in case of 100-25 per cent available moisture regime the crop might have suffered from moderate moisture stresses due to prolonged interval of irrigations and from severe moisture stresses in moisture regime receiving no irrigation in kharif.
These stresses lowered the daily growth and mineral absorption rates (Tables 19 to 22), and decreased the concentration of nitrogen and phosphorus in leaves and stem resulting in decreased uptake of nutrients in various stages of crop (Tables 38 to 45). Similar findings have been reported by Miller and Duley (1925) who studied such relationship in corn at an optimum moisture level and found that it was greater than that of comparable plants in soil maintained at higher or lower moisture level with varying soil fertility. The increases in yield attributes were not appreciable, except in 100-kernel weight in summer. The 100-kernel weight increased with increasing phosphorus level within the same moisture regime. However, the 100-50 per cent available moisture regime combined with 25 kg nitrogen and 150 kg P_2O_5 recorded highest 100-kernel weight (Tables 32 and 35) in both seasons, on account of greater yield contents migrated to pod yield containers from leaves and stems. These increased yield contributed to the greater pod weight.

The pod yields due to interaction effect increased (Tables 29 and 30) with increase in phosphorus levels within the same moisture regime. The effect was more pronounced in moisture regime 100-50 per cent available moisture combined with phosphatic fertilizer. This occurred
because the plants were supplied with adequate moisture, nutrients and aeration in all three phases of yield formation and as such, the capacity for yield container and for filling in pods was greatest resulting in maximum pod yield. The yield capacity of plants in treatment receiving no fertilizer and no irrigation in kharif and without fertilizer with irrigation at 100–25 per cent available moisture regime in summer was lowest as the accumulation of dry matter and quantities of mineral uptake were lowest due to lower soil fertility and moisture deficits. Similar findings have been reported by Greenway et al. (1968) who studied the effect of low and high water potential on uptake in plants and concluded that mineral nutrient uptake is frequently reduced to a considerable degree in plants under deficit and excess soil moisture conditions resulting in decreased yields.

The harvest index values increased progressively with increase in the levels of phosphorus in the same level of nitrogen. The increase in harvest index was more with 25 kg nitrogen level. This might be due to more production of dry matter in case of 50 kg nitrogen application (Tables 17 and 18) which lowered the index values in both seasons. This might have increased the sink size of stem and lowered yield. Such findings have been reported by
Vogel et al. (1963) in winter wheat due to high fertility and high moisture level at the time of stem elongation.

The oil content in kernel increased with increase in phosphorus level within the same moisture regime. The highest oil percentage obtained was 55.52 in kharif and 56.25 in summer (Table 37) in 100-50 per cent available moisture regime with 25 kg nitrogen and 150 kg $\text{P}_2\text{O}_5$ per hectare followed by 50 kg nitrogen and 150 kg $\text{P}_2\text{O}_5$. The increase in oil content was due to largest quantities of synthates translocated from leaves to pods in 100-50 per cent available moisture regime combined with 25 kg nitrogen and 150 kg $\text{P}_2\text{O}_5$ per hectare.

Substantial evidence to show the importance of optimum moisture level and a balanced fertilizer for increasing productivity has been obtained in this study. The pod yield, which is the total reflection of plant growth, flowering and fruit formation was maximum in the treatment receiving irrigation at 100-50 per cent available moisture with application of 25 kg nitrogen and 150 kg $\text{P}_2\text{O}_5$ per hectare. Increasing nitrogen level did not necessarily increase yield. Also increasing the level of moisture i.e., irrigating at 100-75 per cent available soil moisture did not increase the yield, on the other hand decreased yield, so was it in treatment receiving irrigation at 100-25 per cent available moisture.
5.4 Moisture extraction pattern:

The pattern of soil moisture extraction followed closely that of root distribution (Table 25). The crop made maximum use of available moisture from the top 15 cm soil layer. These values decreased in the successive layers in all the moisture regimes in both the years. The top 30 cm depth of soil layer contributed 88.6 and 77.5 per cent of total moisture in kharif and summer, respectively (Fig.16). In kharif, about 11 per cent more moisture from 30 cm depth of soil was supplied as the surface soil remained often wet due to intermittent rains in kharif season.

Higher per cent of moisture depletion from the surface layer was due to the combined losses of moisture through evaporation and extraction of moisture by roots. Lower depletion in the next layer was because of the loss of evaporation component and slightly lesser distribution of roots in that layer. The lowest depletion rate from the deepest soil layer may be due to the least distribution of roots in that region. Similar pattern of moisture depletion has been reported by Dillewijn (1952) who studied the moisture extraction pattern in sugarcane. Chandra Mohan (1970) working on efficient water management for groundnut reported that wetting of soil need be done only upto a depth of 30 cm where more than 80 per cent of effective roots were found.
5.5 **Consumptive use of water:**

Higher values of consumptive use of water (Tables 64 and 65) were registered in frequently irrigated regime i.e., 100-75 per cent available moisture probably because the surface layer under this regime remained wet for a longer time creating favourable condition for potential evapotranspiration for more days than in other treatments where irrigations were applied at higher tension or lower regimes. The increased losses by evaporation from plots receiving more water were reported by Keen (1922), Fisher (1923) and Chandani (1947) and Cheema and Moolani (1970) in sugarcane. The values increased slightly as levels of fertilizers increased in both seasons. This might be due to the increased transpiration on account of greater size of canopy in treatments receiving increased levels of fertilizers. The values were higher in summer (Table 66), because of higher evaporative demand. The increase in consumptive use in 100-75 per cent available moisture regime was 3 and 9 per cent in kharif and 9 and 16 per cent in summer over 100-50 and 100-25 per cent available moisture regime, respectively.

5.6 **Rates of consumptive use of water:**

The increase from 2.33 to 7.01 mm in kharif (Table 64) and from 4.05 to 8.15 mm in summer (Table 65) in the rate of consumptive use of water from germination
through early vegetative period to flowering was due to the increase in the crop canopy. The daily consumptive use of water increased and reached maximum of 7.56 mm in kharif and 8.54 mm in summer during pod development stage. This might be due to increase in the transpiring area of the canopy and increased physiological activity. At maturity the consumptive use decreased rapidly due to the senescence of the crop and yellowing of leaves. Similar findings have been reported by Matlock et al. (1961) on the consumptive use of water in groundnut. It was lowest in germination and maturity stages and highest during peak flowering and pod development period. Chen et al. (1964) conducted irrigation experiment and found that the most critical stage in groundnut was peak flowering and fruiting stage as the rate of consumptive use of water during this period i.e., 50-80 days of crop was maximum. Joshi and Kabaria (1972) who analysed the effect of rainfall distribution on yield of groundnut observed that the 'r' and 'b' values were highly significant for yield with rainfall received during full pegging to pod development stages i.e., 50-80 days of crop. England (1963) found lesser consumptive use of water in oats in seedlings stage and harvesting stages and highest consumptive use in rapid growing period due to greater canopy. Monteith (1959) showed yellowing of leaves in harvesting stage in crops
affected the consumptive use because of higher albedo or reflection coefficient values. Bennett et al. (1966) obtained similar rates of consumptive use of water in cotton.

The rates of consumptive use of water in various stages of crop were highest in both seasons in moisture regimes irrigating at 100-75 per cent available moisture as the crop did not suffer from moisture stresses. This was followed by treatment receiving irrigation at 100-50 per cent available moisture. The least rates were in treatment receiving no irrigation in kharif and irrigating at 100-25 per cent available moisture in summer. These variations were due to degree of canopy in different stages and the extent of dry matter production. These two were highest in treatment receiving irrigation at 100-75 per cent available moisture, recording highest rates of consumptive use of water. Slatyer (1969) showed that in most crops, growth and development proceeded unimpaired and growth was maximal at high soil water potential.

The rates of consumptive use of water was higher in summer than in kharif on account of higher evaporative demand (higher temperature) and larger canopy.
5.7 Water use efficiency:

The most promising way to increase water use efficiency is to encourage the economic yield through optimum production of dry matter rather than decrease water use. The dry matter production in turn depends upon chlorophyll content of leaves, albedo, and canopy area.

In the present study the treatment receiving no irrigation in kharif recorded highest water use efficiency of 3.03 (Table 67) on account of marginal use of available moisture. The least i.e., 2.69 in kharif and 1.58 in summer was in treatment receiving irrigation at 100-75 per cent available soil moisture. Though moisture regime receiving irrigation at 100-75 per cent available moisture produced maximum dry matter, it did not record highest pod yield on account of lower daily rates of absorption of nitrogen and phosphorus in all stages of growth. This reflected in lesser quantities of translocation of metabolites resulting in lower yield and lower water use efficiency.

In summer, treatment receiving irrigation at 100-50 per cent available soil moisture recorded maximum water use efficiency of 1.86 on account of its higher nutritional status and dry matter production in all stages of growth.
In both seasons the water use efficiency increased with increase in levels of fertilizers and more progressively with increase in levels of phosphorus within same level of nitrogen. The highest water use efficiency was 3.24 in kharif and 1.94 in summer in treatment receiving 25 kg N and 150 kg P₂O₅ per hectare due to higher chlorophyll content, dry matter production and nutritional values in all stages of growth resulting in higher water use efficiency. Highest water use efficiency of 3.35 in kharif and 2.38 in summer in treatment receiving irrigation at 100-50 per cent available soil moisture coupled with treatment receiving application of 25 kg nitrogen and 150 kg P₂O₅ per hectare might be due to interaction effect on account of higher dry matter production, chlorophyll content and higher nutritional level in all stages of groundnut resulting in maximum water use efficiency. These results are in agreement with the findings of Sestack (1966) who reported that plants having more chlorophyll had less albedo and partitioned more energy for plant growth and absorption of nutrients resulting in water use efficiency. Haise and Viets (1957) who worked on water requirements as influenced by fertilizer use in crops and Raheja et al. (1961) reviewing the efficiency in use of irrigation water in relation to application of fertilizers concluded that increasing the fertility of soil reduced the quantity of water expended per unit of dry matter produced though the total quantities expended were more. Gupta et al.
(1970) who studied the effect of fertilizer application on the moisture needs of 'NP 710' wheat in light textured alluvium found that a combination of nitrogen and phosphatic fertilization enabled maximum utilisation of moisture by the crop even at highest moisture levels.

The water use efficiency was more in kharif season than in summer. This might be due to more evapotranspiration on account of higher temperature and longer hours of sunshine that (Appendix I b) prevailed in summer.

5.8  **Irrigation requirement:**

The total quantity of irrigation water applied (Table 2) was highest in treatment receiving irrigation at 100-75 per cent available moisture followed by the treatment receiving irrigation at 100-50 per cent available soil moisture. This might be due to increased transpiration on account of larger canopy and secondly due to more evaporation from the surface soil, which remained wet for longer period on account of frequent irrigations. Similar findings are reported by Chandra Mohan (1970), working on efficient water management for groundnut.

The irrigation requirement was about 80 per cent more in summer than in kharif in all the treatments, which might be due to higher evaporative demand on account of higher
temperatures prevailed in summer and also due to longer duration of the crop.

5.9 **Scheduling irrigation:**

In the present study the moisture regimes have significantly affected the yield of groundnut. The moisture regime receiving irrigation at 100-50 per cent available soil moisture gave maximum yield in both seasons followed by the moisture regimes receiving irrigation at 100-75 and 100-25 per cent available moisture regimes. The yield of moisture regime irrigating at 0.4 atm tension in summer was on par with the yield of 100-50 per cent available moisture regime. Both the moisture regimes receiving irrigation at 100-75 and 100-25 per cent available moisture decreased the yield of groundnut to a considerable extent. The value of coefficient of correlation between daily consumptive use of water in moisture regime irrigating at 0.4 atm tension and the daily evaporation from sunken screen evaporimeter was highly significant \( r = 0.583 \). Similarly, the value of coefficient of correlation between daily consumptive use of water in moisture regime receiving irrigation at 100-50 per cent available moisture with the evaporation loss from sunken screen evaporimeter was significant \( r = 0.430 \) (Table 68). Both these devices are simple and give more accurate estimates of consumptive use of water. Hearn and Wood (1964) and Dagg (1965) gave the idea that the
pan evaporation rate is in better agreement with evapotranspiration. Ekern (1966) reported that the simplest and most successful method in presence of advective energy is the use of evaporimeter. Ward (1963) reported that evaporimeter gave more accurate estimates of consumptive use of water.

5.10 **Response analysis:**

5.10.1 **Yield - moisture response:**

The nature of yield response to moisture was quadratic (Fig. 18(a) ) in both seasons. The response was highest in 100-50 per cent available moisture regime followed by 100-75 per cent available moisture regime. In moisture regime irrigating at 100-50 per cent available moisture, the crop might have been provided with optimum moisture, aeration, and nutrients. The least responsiveness was in moisture regime irrigating at 100-25 per cent available moisture. This may be due to reduced photosynthetic activity of the crop under water stress conditions.

5.10.2 **Yield - fertilizer response:**

The nature of yield response to phosphatic fertilization was linear (Fig. 18 (b) ). The response between the graded levels of phosphorus has been maintained in both seasons. The response obtained in summer was more than in kharif. This is because of greater rates of growth.
and nutrient absorption during all the yield formation stages of crop on account of higher temperature and longer hours of sunshine in summer. It may be also inferred that the dose of P$_2$O$_5$ for the best production of groundnut lies beyond the highest dose of 150 kg per hectare chosen in the present study for the soil on which the experiment was conducted. This means that the application of higher dose of P$_2$O$_5$ is necessary for getting higher yields.

5.11 Economics of fertilizer application:

In fixing the economical levels of fertilizer, not only the extent of increase in yield is taken into consideration but also the economics of the fertilizer application. In working out the economics, the cash return per rupee spent on fertilizer gives a good criterion. In the present study the highest cash returns are obtained in moisture regime irrigating at 100-50 per cent available soil moisture combined with fertilizer treatment receiving 25 kg nitrogen and 150 kg P$_2$O$_5$ per hectare in both the seasons (Tables 71 and 72). This is due to highest yield produced on account of higher rate of absorption of nutrients, dry matter production, reproductive efficiency and increase in shelling percentage and kernel weight. The lowest cash return was in fertilizer treatment receiving application of 25 kg nitrogen and 50 kg P$_2$O$_5$ per hectare combined with
moisture regime receiving no irrigation in kharif and with moisture regime receiving irrigation at 100-25 per cent available soil moisture in summer. This might be due to decrease yield on account of lower rate of nutrients absorption, dry matter accumulation and decrease in yield attributes because of soil moisture stress in flowering and pod development stages. The highest cash return was ₹.9.04 in kharif and ₹.10.60 in summer per rupee spent on fertilizer in case of moisture regimes irrigation at 100-50 per cent available moisture with 25 kg nitrogen and 150 kg P₂O₅ per hectare. This highest profit is due to the greatest interaction effect of moisture regime and fertilizer levels. The cash return did not increase with the increase in the levels of nitrogen as the response fell off rapidly but it increased with increasing level of phosphorus within the same level of nitrogen. The net return was more by about ₹.1.00 to ₹.2.00 in summer than in kharif. This was due to the increased yield of groundnut on account of higher temperature and longer period of sunshine in summer.

5.12 Estimating profits:

It is seen from Fig.19 that profit increased with the increase in the level of fertilizer to a certain point and then began to decrease as the additional fertilizer was added. The point of maximum profit occurred where the
distance between the cost line and the income curve was greatest and it just touched the dotted line drawn parallel to the fertilizer cost line. In case of nitrogen the maximum profit occurred at 25 kg nitrogen per hectare while in case of phosphorus it went on increasing up to 150 kg phosphorus per hectare. Similar illustrations have been given by Honway and Bennet (1957) for maize and for jowar by Tippannavar (1958). Application of lower level of 25 kg nitrogen per hectare with highest level of 150 kg $P_2O_5$ per hectare to groundnut seems to be most profitable.