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Effect of Planting Pattern and Plant Density on Physiological Characteristics and Yield of Peanut (*Arachis hypogaea* L.) in Iran

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Abstract: This research was conducted to evaluate the effects of planting pattern and plant density on physiological characteristics and yield of peanut (*Arachis hypogaea* L.) in Bandar Kyashahr investigating field in growing season 2002. The experiment of design was a randomized complete block design with three replications. Planting pattern (square and rectangular arrangement) and plant density (3, 5.3, 8.3 and 14.8 plants m^{-2}) were two factors studied. The results showed that the planting patternsignificantly affected the leaf area index from 45-90 days after planting square planting pattern significantly and square planting pattern had higher LAI than the rectangular pattern. Plant density was significantly affected in total growth period on leaf area index was significant effect. The effects of planting pattern and plant density on Crop Growth Rate (CGR), Pod Growth Rate (PGR), Partitioning Factor (PF) and Harvest Index (HI) was also significant. Planting pattern did not affected on (Pod Filling Period) PFP and shelling percentage. In square planting pattern and plant density of 8.3 plants m^{-2}, pod yield was greater than treatments.

Key word: Peanut (*Arachis hypogaea* L.), planting pattern, plant density, physiological characteristics, yield, Iran

INTRODUCTION

Determination of the optimum plant population density necessary for optimal yield is a major agronomic goal. Sowing at those seed rate results in optimal plant population density reduced seed costs, lodging and also ameliorate disease problems (Hosseini *et al*., 2001). Two general concepts are frequently used to explain the relationship between row spacing plant densities and yield. First, maximum yield can be obtained only if the plant community produces enough leaf area to provide maximum isolation interception during reproductive growth. Secondary equidistant spacing between plants will maximize yield because it minimizes inter plant competition (Egli, 1988). The peanut (*Arachis hypogaea* L.) in an important food legume throughout much of the tropics and subtropics of the Americas, Africa, the Indian subcontinent, Asia and Australia (Bell *et al*., 1987).

The optimum plant density and planting pattern at one site may not apply at other locations because regional variations in weather and soil mean the further traits are needed at each site to validate general recommendations (Azam-Ali *et al*., 1993). Although, the greatest recorded yield for the peanut is 9.6 ton ha^{-1}, current commercial yields are 3 about to 4 ton ha^{-1} in many countries and as low as 1 ton ha^{-1} in others (Hammer *et al*., 1995). Plant density and planting pattern are major cause of inability to achieve potential yield in irrigated and dry land production (Bell *et al*., 1991).

The response of peanuts to plant density has been investigated in many areas of the world. Investigation of growth and yield performance of peanut (*Arachis hypogaea* L.) with special reference to arrangement by Auma has been conducted. The results have showed that leaf area index, crop growth rate, pod growth rate and pod and kernel yields have increased by the square planting pattern (Jaffar and Gardner, 1988). Kvien *et al*. (1988) reported that increasing plant density from 2-20 plants m^{-2} increased LAI from 2.2-4.8 and 3.5-5.7 for florunner and Southern runner cultivars, respectively. Pod yield also has increased from 310-580 and 190-550 g m^{-2} for florunner and Southern runner, respectively (Kvien *et al*., 1988).

Effect of row spacing has been studied by Mixon (1989). The results have showed that the four-row spacing (height plant density) yielded 7% more pod than the two-row spacing (Mixon, 1989). Oram demonstrated that pod yields (in Africa) were greatest when Plant Population Density (PPD) ranged from 98000-274000 plants ha^{-1} whereas, Pillips and Norman observed only a slight

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response to PPD >74100 plants ha^{-1} (Gardner and Auma, 1989). Wright and Bell (1992) also studied the effect of plant population on peanut. He suggested that in groundnut by reducing plant density pod yields were increased (Wright and Bell, 1992). Bell *et al.* (1987) showed that square planting pattern produced significantly greater pod yields than the conventional commercial practice of rows 90 cm apart (Bell *et al.*, 1987). The different groundnut cultivars were grown in Srilanka at 10, 20 and 30 plants m^{-2}.

Leaf area index, crop growth rate, pod growth rate and partitioning factor increased with increasing plant density in all cultivars. Increasing of plant density were decreased harvest index in all cultivars except pronto (Samarasinghe and Tannar, 1989).

According to Papastylianou (1995) maximum yield was obtained with 7-8 plants m^{-2} and yield gradually increased to a maximum with 11-14 plants m^{-2}. Yield was unaffected by further increasing plant density while at <7-8 plants m^{-2} it was significantly reduced (Papastylianou, 1995). Plant in narrow row and twin-row-planting patterns compared to the conventional had significantly greater ground cover, LAI canopy light interception, CGR and pods and kernels (Gardner and Auma, 1989).

Yilmas (1999) in a study on the effect of different plant densities of two groundnut cultivars found that highest yield was obtained at 60×15 cm spacing (Yilmas, 1999). Furthermore, Madkour *et al.* (1992) showed that effects of row spacing on seed and pod yields was significant and 50 cm row spacing than showed higher yields, componed to 60 cm row spacing (Madkour *et al.*, 1992). Reduction of plant spacing (increasing plant density) from 40-5 cm increased pod yield (Kvien and Bergmark, 1987).

An experiment was conducted in America showed that pod yield for all cultivars used generally improved when row spacing was reduced from a wide spacing of 91.4 to an intermediate spacing of 45.7 cm (Kirby and Kitbamrooning, 1986). Influence of row spacing on peanut yield has also been investigated by Hauser and Buchanan (1981).

The results have showed that groundnut in close-row patterns has yielded about 14% more than the conventional spacing (Hauser and Buchanan, 1981). James research on planting pattern and row spacing of peanut. Their results showed that peanut pod yield was higher in standard twin row planting patterns than when grown in single row planting patterns. Planting peanut in the narrow twin row pattern did not increase peanut pod yield over the standard twin row planting pattern (Hammer *et al.*, 1995).

MATERIALS AND METHODS

The experiment was conducted in Bandar Kyashahr experimental field at Guilan province in 2002. The soil type was clay with pH = 7.6 and electrical conductivity = 0.29 DS/M. A randomized complete block design was used with factorial combinations of four plant densities and two special arrangements with three replications. The plant densities were 30000, 53000, 83000 and 148000 plants ha^{-1} the special arrangement including two planting pattern (square and rectangular). Each plot size was 30 m^2 (6×5 m).

Tiram fungicide applied before sowing. Uniform seeds of peanut (NC_2 cultivar) were sown in each plot under dry land conditions. Before sowing (according to the results of soil analysis) 200 kg ha^{-1} super phosphate triple was applied. Furthermore, 80 kg ha^{-1} N on sowing time and 20 kg ha^{-1} after 1st hand weeding was applied. Sampling were taken at random from each plot on unit area basis. For calculation of LAI samples were taken from 0.5 m^2 area of each plot every is days starting 1 month after sowing. At final harvest dry mass of haulm and the dry mass of pods were measured after aven drying at 70°C for 48 h. Crop Growth Rate (CGR), Pod Growth Rate (PGR) and Partitioning Factor (PF) were estimated using the following equation:

HI = Pod number x weight per pod/total dry matter (Harris and Natarajan, 1987)

CGR = Haulm yield+(pod yield ×1.65)/T1 (Williams, 1992)

PGR = (Pod yield ×1.65) (T1 - T2 - 15) (Williams, 1992)

PFP = Pod yield/PGR (Williams, 1992)

PF = PGR/CGR (Williams, 1992)

T1 is the number of days from sowing to harvest and T2 is the duration from sowing to 50% flowering. Shelling percentage was calculated by dividing of seed weight to pod weight.

Kernel yield was calculated as the ratio of pod yield x shelling percentage (Bell *et al.*, 1991). The data were subjected to analysis of variance using SAS figures EXCEL were drown using.

RESULTS

Leaf Area Index (LAI): The analysis of of variance planting pattern and plant density on leaf area index showed that planting pattern till 29 days after sowing had no effect on LAI (Table 1). Square planting pattern had greater effect on LAI than rectangular on in the during of 45-90 days after sowing (Fig. 1). LAI decreased in the

Table 1: Summary of experimental treatments showing plant spacing (cm)

	Spatial ratio (inter-row: intra row)	
Plant density	1: 1 (square)	1: 3 (rectangular)
3	57.5×57.5	33×100
5.3	43.5×43.5	25×75
8.3	34.5×34.5	20×60
14.8	26×26	15×45

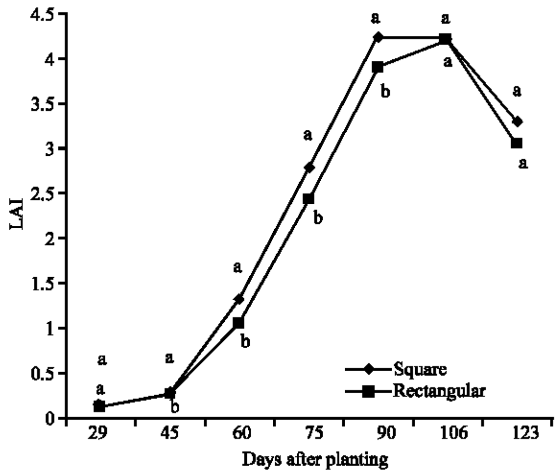

Fig. 1: Effect of planting pattern on LAI during of growth stage of peanut

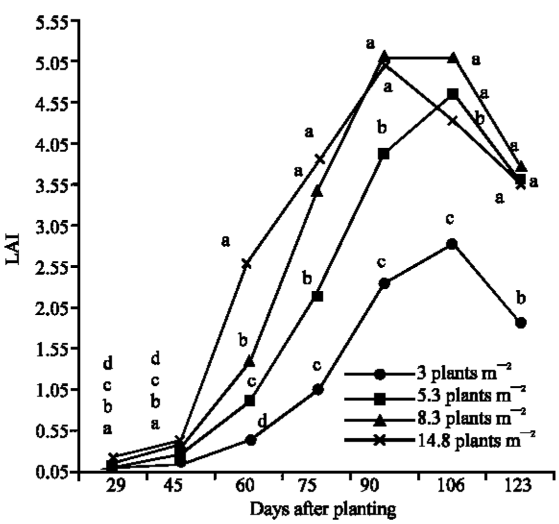

Fig. 2: Effect of plant density on LAI during of growth stage of peanut

during of the 106-123 days after planting but not effected by planting pattern in this time. With not significant deference in planting pattern, the LAI was maximum in the rectangular at 106 days after planting. LAI was also affected significantly by plant density in various stages of growth. LAI since planting to 45 days after planting in density of 14.8 plant m^{-2} was significantly higher than others but from 60-90 days after planting, LAI in 8.3 density treatments raised considerable (Fig. 2) in 8.3 from 90-106 days after planting, LAI in 14.8 plant m^{-2} reduced. From 106-123 days after planting, amount of LAI decreased in all level of density treatment. Interaction of planting pattern and plant density in total growth stage was not significant.

Crop Growth Rate (CGR): CGR was significantly higher in square planting pattern than rectangular (Table 2). CGR did not show similar trend among different plant densities. In increased significantly from 3-8.3 plant m^{-2} but declined in 14.8 significantly. Interaction of planting pattern and plant density was not significant.

Pods Growth Rate (PGR): Pod Growth Rate (PGR) was influenced significantly by planting pattern. Square planting pattern induced higher PGR than rectangular was greater than rectangular. Plant density had significant effect on PGR. The influence of different density treatments on PGR was similar to CGR (Table 2).

Partitioning Factor (PF): Both planting pattern and plant density treatments effected the partitioning of dry matter in peanut plants significantly (Table 2). The partitioning factor in 8.3 plants m^{-2} was higher than other plant densities.

Partitioning factors increased with increasing density from 3-8.3 plants m^{-2} but decreased in 14.8 plant m^{-2}. On PF was significant and square planting pattern was greater than rectangular. The interaction of planting pattern and plant density on partition factor was not significant.

Shelling percentage (seed to pod ratio): Planting pattern could not affect shelling percentage of peanuts. Whereas plant density affected it significantly (Table 3). Shelling percentage was highest in 8.3 plants m^{-2} and fewest in 14.8 plant m^{-2}. Interaction of planting pattern and plant density in this case did not significant.

Pods Filling Period (PFP): Pods filling periodof peanuts was not affected by planting pattern but was affected by plant density (Table 2). Pod filling period was increased by increasing plant density (Fig 2). Interaction of planting pattern and plant density was not significant.

Harvest Index (HI): HI in square planting pattern was significantly higher than rectangular (Table 3). This index of growth was also affected by plant density. 8.3 plants m^{-2} had higher than others. Interaction of planting pattern and plant density was not significant.

Table 2: Effect of planting pattern and plant density on different physiological characteristics and yield of peanut

Source variation	df	CGR	PGR	PF	PFP (days)	HI	Kernel yield (ton ha^{-1})	Pod yield (ton ha^{-1})
Replication	2	0.35^{NS}	1.34*	0.0087^{NS}	5.04^{NS}	12.12^{NS}	263986.69*	83744.67^{NS}
Planting pattern	1	1.9*	5.05**	0.0034*	1.04^{NS}	26.04*	912350.41**	454320.31**
Plant density	3	2.29**	3.57**	0.0057*	19.15*	56.37*	743679.61**	343331.69**
Interaction	3	0131^{NS}	0.33^{NS}	0.0025^{NS}	1.15^{NS}	5.15^{NS}	50250.81^{NS}	55022.45^{NS}
Error	14	0.183	0.284	0.0016	2.85	7.84	32658.85	22897.50
Coefficient variation		6.28	7.34	4.64	4.27	5.125	5.82	7.22

NS ** and *non significant, significant in 1% and significant in 5%, respectively

Table 3: Different characteristics of peanut as influenced by planting pattern and plant density

Treatments	CGR (g m^{-2})	PGR (g m^{-2})	PF	Shelling percentage	PFP (days)	HI	Kernel yield (ton ha^{-1})	Pod yield (ton ha^{-1})
Planting pattern								
Square	8.0^a	7.5^a	0.95^a	67.85^a	40^a	0.29^a	2.20^a	3.2^a
Rectangular	7.5^b	6.5^b	0.87^b	65.91^a	40^a	0.27^b	1.90^b	2.9^b
Plant density								
3 plants m^{-2}	6.7^c	6.0^c	0.85^b	67.50^{ab}	38^b	0.24^b	1.70^c	2.6^c
5.3 plants m^{-2}	7.5^b	6.5^b	0.90^{ab}	67.50^{ab}	39^b	0.29^a	2.10^b	3.2^b
8.3 plants m^{-2}	8.0^a	7.2^a	0.95^a	68.66^a	40^b	0.32^a	2.30^a	3.4^a
14.8 plants m^{-2}	7.2^b	6.3^b	0.87^{ab}	66.33^b	42^a	0.28^a	2.04^b	3.1^b

Means within a column or each factor whit the same letter are not significantly different at the 5% level according to Duncan's multiple range tests

Kernel yield: Similar to harvest index, planting pattern influenced the kernel yield of peanuts with higher amount of kernel yield in square plant highing (Table 2 and 3). Results showed significant effects of plant density on kernel yield with highest amount in 8.3 plants m^{-2} in compare to others. Kernel yield raised with increasing plant density from 3-8.3 plant m^{-2} but declined when plant density reached to 14.8 (Table 2). Interaction of planting pattern and plant density was not significant.

Pod yield: Planting pattern had significant influence affected on pod yield and greater yield was obtained in plots with square planting pattern (Table 2 and 3). Plant density had significant affected on pod yield of peanut and 8.3 plants m^{-2} was higher than others. Pod yield of peanut increased with increasing of plant density from 3-8.3 plants m^{-2} but with increasing of plant density to 14.8 plants m^{-2} pod yield decreased. Interaction of planting pattern and plant density was not significant.

DISCUSSION

During 45-90 days after planting, LAI in square planting pattern increasing of extension of plant LAI relative to rectangular planting pattern in due to increasing extension of plant, raised more than in rectangular one. Point that's in 90 days after planting that spacing between rows and also spacing between plants in intra rows was filled completely, LAI in square planting pattern relative to rectangular further increased. In square planting pattern was faster canopy closure therefore, light interception was occur early relative to rectangular planting pattern (Bell *et al*., 1987). Increasing of LAI in square planting pattern induced better distribution of light in canopy, higher absorption of nutrients from soil and low competition between plants. These factors induced CGR in square planting pattern relative rectangular was greater. Optimum of planting pattern provide increasing of crop growth and development because extended of leaf area and low light from canopy to soil surface absorptive therefore, directed effect between CGR and among of light absorption.

Square planting pattern was greater affect on PGR. In square planting pattern, LAI and CGR was greater relative rectangular planting pattern. Many of researchers accepted distribution of assimilation between different partitions under agronomy and environment factors. Distribution of assimilation depended to origin of production of assimilation in above partitions different physiologically sink for assimilation and capacity of translocation of assimilation between source and sink. Partitioning factors explain translocation of assimilation to pods. Researchers explained filling of pod and remobilization from parts different of plant to pods with partition factor. Partitioning was increasing with increase of seed growth. Different researches showed that in Virginia cultivars of peanut remobilization of assimilate was conducted in duration of fall leaves. With attention to effect of planting pattern on partitioning was significant can explain that square planting pattern with better distribution of plants and reduce of competition between of plants better partition of assimilate was conducted to pods and height of LAI in square planting pattern good reason from increasing of partition factors in peaut in square planting pattern.

In other hand, LAI in square planting pattern was increase of photosynthesis because between among of photosynthesis white assimilation translocation has significant positive coloration therefore among of assimilation to pods probably many increased.

Researches showed that CGR' PF and PFP, the most effective of to pod yield of peanut. Because PFEP in square and rectangular planting pattern was not significant therefore above physiologically factors (CGR, shelling percentage and PF) major effective factors on pod yield of peanut. Kvien *et al.* (1988) was obtained that shelling percentage was not affected by row pattern. Samarasinghe and Tannar (1989) was found that final seed yield in the Spanish type cultivars due to greater partitioning of dry matter into the seeds and a higher of dry matter. In the bunch cultivars (such as NC2) to increasing of space between plants increasing of lateral spread was occurred therefore, LAI in this arrangement increased. Photosynthesis was observed to be linearly related to canopy interception of solar radiation hence absorbed solar energy is a primary factors controlling crop growth rate and plant development in crop plants (Gardner and Auma, 1989). From sowing data to 45 days after planting with increase of plant density, LAI was increase to only of higher plants in unit area. In 60-90 days after planting LAI in 8.3 plant density many increased relative to other plant densities and with LAI in 14.8 plants density was equivalent. In this stage, sink capacity and pod filling was formed. In 90-106 days after planting LAI was constant in 8.3 plants density but LAI in 14.8 plant densities was reduced. With increase of plant density to optimum range among of dry matter product in unit area in unit data (CGR) was increased but with increase of plant density from optimum range CGR among was reduced. Diversity of PGR with plant density was seamed with CGR. Increasing of PGR until 8.3 plant density was due to increasing of leaf area and assimilation product and increasing of CGR. Between LAI and LAD with pod yield of peanut have positive coloration. Therefore, until 123 days sowing pods filling was conducted under diversity of LAI and PF in different plant densities. Decrease of LAI in 90 days after sowing in 14.8 plants m^{-2} was more effective on reduce of PGR. The other factors for reduce of pods growth was reduction of assimilation partition to pods in 14.8 plant density because increase of plant density induced of translocation of light compensation point from down of canopy to above of canopy. In other hand, leaves located of under light compensation point have no much photosynthesis therefore, transporting of assimilation to pods in growth stage many reduced because leaves of under of canopy have the most role for duration of pod filling.

The reason of increasing of PF, depended to increasing of photosynthesis capacity until 8.3 plants m^{-2} and translocation of assimilation to pods because among of translocation of assimilation to pods have significant positive coloration therefore, the reason of height in 8.3 plants m^{-2} duration in 60-106 days after planting PF was many increased probably but in 14.8 plant m^{-2} shading interaction of leaves increased that in this factors decreased net assimilation rate leaves and remobilization. Hence, height of plant density of peanut at constant and optimum planting rate reduces intra-plant competition during juvenility, enhances plant growth, ground cover and light interception and leads to higher total dry matter and pod yield (Gardner and Auma, 1989; Jaffar and Gardner, 1988).

CONCLUSION

The results of this study shows that the decrease of PF in 14.8 plants m^{-2} is result of decrease of translocation of photosynthesis to pods therefore for filling of pods needs higher time that pods receive to growth and physiologic maturity. Increase of plant density from 3-8.3 plants m^{-2} pod yield increased but from 14.8 plants m^{-2} pod yield decreased because higher among of PFP low among of CGR' PGR and LAI was conducted.

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