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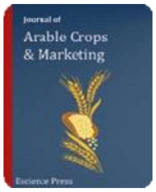

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Effect of Nitrogen and Phosphorus Application Rate on Peanut (*Arachis Hypogaea* L.) Phenology, Yield and Soil Nutrient Status

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ABSTRACT

Purpose: Over and under dose application and of nitrogen (N) and phosphorus (P) leads to inferior growth and yield reduction in field crops. Different nutrients have synergetic and antagonistic effects according to soil properties, climate, crop type and management practices at the same time. **Research Methods**: In this field study, we tried to explore the combined effect of N and P on peanut phenology, yield and soil N and P status. Three N (N_1=20, N_2=40, N_3=60 kg ha^{-1}) and three P (P_1=60, P_2=80, P_3=100kg ha^{-1}) application rates were applied in a split-plot complete randomized design in 2016 and 2017 growing seasons of peanut, while after harvesting of peanut field was fallow. **Findings**: Our results demonstrated that combined or individual application of N and P not affected phenophases of peanuts (germination, flowering and pegging) except physiological maturity, and a low rate of N application increased maturity duration time in peanut. While pod production in low N doses was more as compared to high dose application of N and P, except N_3P_2 in both years, a greater number of pods attained less grain weight and lower yield. Concurrently, a higher dose of N and P individually produced higher yield (2614, 2647 in N_3, 2549, 2527 kg ha^{-1} in N_2) and lower yield was quantified 2216 and 2205 in N_1 in both years (2016-2017) respectively. Similarly, 2658, 2647, and 2496, 2507 kg ha^{-1} were weighted in P_3 and P_2 respectively. But their combined effect was non-significant ($P>0.05$). In the case of soil total N and available P, N increment doubled (~0.8 g kg^{-1}) as compared to initial N status regardless of N application rate but P had no effect on available P contents in upper soil (0-15 cm) surface. So, peanut cultivation can be a promising strategy for N increment in a semi-arid area of Pakistan. **Limitations**: Due to the limited availability of funds, we analyzed areas of topsoil (0-15). It will be better to do soil analysis in depth for further studies. These findings are valuable for researchers, farmers, and regional agriculture departments, because alternation in nitrogen rate application didn't change the soil N level with the combination of phosphorus in peanut. So, Findings suggested that low N application was enough for peanut cultivation. Nitrogen and phosphorus have a significant effect on the growth and yield of peanuts. Peanut crop needs the half amount of nitrogen than phosphorus because it is a leguminous crop and has nitrogen factories in the root nodules.

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INTRODUCTION

An increasing population of the world is leading to food security threats through the over-exploitation of agricultural resources(FAO 2009). Monoculture cropping systems deteriorate soil physio-chemical properties (Lal 1997, Pin and Schiller 2016). Induction of grain legume crops in the cropping system not only enhances soil nutrient status as well as the crop yield of the subsequent crop (Naab *et al.,* 2017). However, yield and soil quality enhancement are closely related to the legume species, initial soil fertility status and crop management approach (Dello Jacovo *et al.,* 2019; Guzman *et al.,* 2019). In the last four decades, the use of nitrogen has increased seven times to enhance agricultural production to meet dietary needs (Hirel *et al.,* 2007). It can be improved with the sowing of grain legume crops (Watson *et al.* 2017). Moreover, Khaliq *et al*., (2019) identified that the cereal cropping system is deteriorating soil nitrogen (N) and reducing yield. Groundnut in Punjab is grown for yield and livestock feed and industrial applications (Naeem-ud-Din *et al.,* 2012). Although, it can be sown for the improvement of soil nutrient status in a monoculture cropping system.

Legumes crop requires initial N for early development (Biosci *et al.,* 2013), and it is a cost-effective agro-management practice to enhance soil N in semi-arid conditions because other conservation approaches (manure application) can be toxic for soil (Zahran, 1999). Globally, phosphorus (P) is higher in soils, but its availability to plants is a more complex phenomenon than other compounds and minerals (Vance *et al.,* 2003), Physiology and morphology of leguminous crops involved in symbiotic biological nitrogen fixation rhizobia; these are depending upon the availability of the P and N which are limiting edaphic factor (Magadlela *et al.,* 2015; Vance *et al.,* 2003). Leguminous crops require a higher amount of P as compared to non-leguminous crops. P increased N fixing ability, improves physiological activity and critical factor in the peanut yield enhancement (Chirwa *et al.,* 2016).

Availability of P in legume crops not only affect development of nodules, but also help in N acquisition and metabolism (Bogino *et al.,* 2006). Application of P fertilizer is beneficial for growth and development in legume crops. Phosphorus stimulates the growth of roots, increase nutrient-water use efficiency, and also enhance yield. Leguminous crops can prepare their own nitrogen from the environment and they have need potassium and phosphorus for better seed formation (Asiedu *et al.,* 2010). Nodulating legumes require a higher amount of phosphorus as compared to non-nodulating crops. Phosphorus application to the soil is used for the increase of yield in groundnut crop due to played important role in the physiological process of plants. Phosphorus application in peanut improves root development, promotes other nutrient, water utilization and photosynthetic efficiency, which are necessary for increasing dry matter accumulation and yield production (Halder *et al.,* 2017). Nitrogen is key production for legume crops. Amount of nitrogen fertilization is used by the plant, nitrogen absorption and nitrogen fixation by nodules of the root. Development of nodules is affected by different forms of inorganic nitrogen which is responsible for the production of rhizobia (Martinez *et al.*, 2003). Management of nitrogen for groundnut crop is important to enhance the growth and yield (Wang *et al*., 2016). However, the interactive effect of N and P is not completely explored on the growth, yield and soil nutrient status of the soil. Therefore, this study was conducted: i) To explore the combined application of N and P on growth and yield of peanut. ii) To reveal synergistic or antagonistic effects of different application rates of N and P on soil and peanut yield. iii) To determine the short-term changes in N and P soil status after peanut cultivation.

MATERIAL AND METHODS

The trial was executed at Farm Area, University of Agriculture (Latitude = 31°- 44' N, Longitude = 73°- 06' E, Altitude = 184.4m), Faisalabad, Pakistan. Nine experimental treatments were arranged in randomized complete block design (RCBD) with split-plot-arrangement and three replications. Nitrogen application rates (N_1=15, N_2 = 30, N_3 = 45 kg ha^{-1}) were considered as main plot factor while, three phosphorus levels (P_1= 60, P_2= 80, P_3=100 kg ha^{-1}) were randomized in subplots. Seedbeds were prepared by two deep ploughing followed by planking. Seeds were sown by dibbler in lines at 4cm depth by maintaining 45cm and 15cm P × P and R×R distance respectively. A hybrid variety of peanut (Bari-2011) was sown by using a recommended seed rate of 100 kg ha^{-1}. Fertilizer doses of phosphorus and nitrogen (P: N) at a ratio of (32:12) were given on sowing and in split doses respectively. Earthing-up was done for better penetration of pegs to the soil. Water requirement is higher at vegetative stage and low after flowering and pegging. Remaining agronomic applications without those under consideration were remained same for all the experimental units. In addition, initial soil properties and weather conditions were presented in Table1. and Figure 1, respectively.

Table 1. Basic soil properties of experimental location in upper soil (0-15 cm) surface.

Determination	Unit	Value obtained
E.C	dsm^{-1}	1.26
pH	-	7.75
Nitrogen	$g\ kg^{-1}$	0.43
Phosphorus	$g\ kg^{-1}$	5.99
Potassium	Ppm	110
Saturation	%	33
O.M	%	0.21
Sand: Silt: Clay	%	40: 35: 25

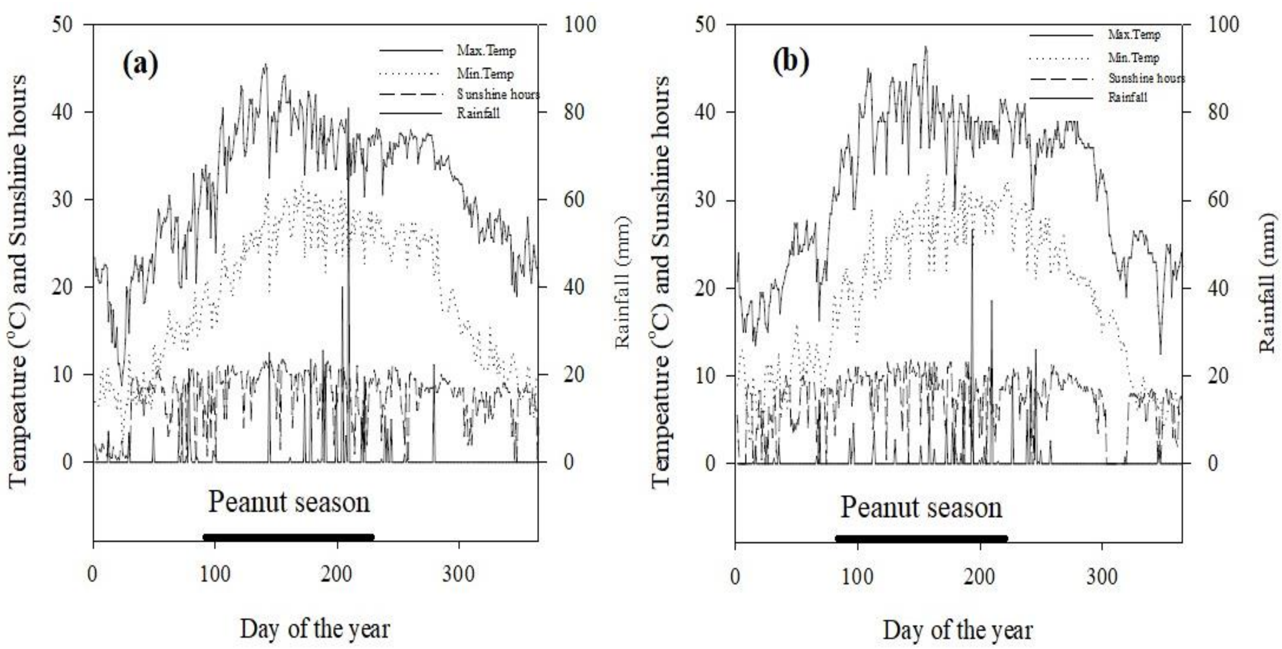

Figure 1. Weather conditions of experimental locations in both growing years (a) 2016 (b) 2017.

Phenophases (Time taken to germination, flowering, pegging and maturity) of crop plants were recorded by daily field visit. Five representative plants were tagged in each plot by leaving appropriate boarder, to minimize the plot boarder effect. Three plants from each plot were harvested for dry matter and leaf area determination at each sampling. Leaf area was determined with 30 days interval by using leaf area meter (JVC model), and finally leaf area index was calculated by applying ratio of leaf and land area. After destructive sampling, each part of the plant is separated and sub-sample of each part with equal weight were kept in oven at 105°C to retard growth process in plant parts for one hour. Then samples were kept in oven at 65°C till constant weight.

Four representative samples were taken before the start experiment at depth of 0-15 cm, and two samples from each plot at the end of the experiment was taken in order to determine soil total N and available P by using Kjeldahl (Carter 1993) and $NaHCO_3$ extraction method respectively. Later on analyzed by using the molybdenum blue method (Murphy and Riley 1962). In depth soil samples was not collected and analyzed due to limitations of funds.

Fisher's analysis of variance (ANOVA) was used, and treatment means were differentiated at 5% probability by using least significant difference (LSD) using computer driven software SPSS. 20.Variation in soil N and P between initial and last soil sampling were reanalyzed by keeping year as third variable and variation percentage induced by N, P, years, Error, and other factors were computed based on sum of squares in ANOVA.

RESULTS AND DISCUSSION

Peanut didn't show any significant variations in its phenological parameters during both study years 2016 and 2017 except for maturity, as days to maturity varied due to impacts of different levels of nitrogen (N), not by phosphorus (P). During germination stage, there happened no significant difference in days to germination due to impacts of different levels of N and P. Maximum days to germination were seen in treatment N_1 with values of 12.78 and 12.44 in years 2016 and 2017, respectively, whereas for phosphorus same non-significant trend was seen with maximum values in P_1 viz. 12.56 days and 12.22 days, in 2016 and 2017, respectively (Table 3). The interactive effect of N and P was also non-significant for both study years. The interactive effect of N_1 with all P levels showed higher values of days to germination during both study years as compared to other interactions, but overall, the individual as well as the interactive effect of treatments was non-significant during both growth seasons as shown in Table 3. Minimum days to germination were taken in treatments N_3 whereas, for P it was in P_3 treatment during both years (Table 3).

Taking into consideration the flowering phase, peanut cultivar was thoroughly examined during both study periods, but it was noted there was no significant impact of individual treatment as well as interactive effect of treatments on days to flowering. Though the significance trend was same as like germination phase but highest number of days to flowering were seen in N_2 treatment with values of 25.56 days and 25.00 days during 2016 and 2017, respectively given in Table 3. Considering the individual treatment effect for P, though all the treatments had higher days to flowering but P_3 had the well noted highest values viz. 25.56 days and 25.22 days during 2016 and 2017, respectively. The flowering period if compared for both seasons, then it was seen for 2017 it was bit longer than 2016 among all the levels of N and P (Table 3).

Table 2. Peanut phenology as affected by nitrogen (N) and phosphorus (P) in both growing years.

Treatment	Stages	Days to Germination		Days to Flowering		Days to Pegging		Days to Maturity	
Nitrogen	Year	2016	2017	2016	2017	2016	2017	2016	2017
N_1		12.78 A	12.44 A	25.11 A	24.33 A	36.00 A	35.89 A	129.67 A	128.66 A
N_2		12.11 A	12.10 A	25.56 A	25.00 A	36.44 A	36.00 A	129.89 A	128.11 AB
N_3		12.00 A	11.89 A	24.88 A	24.33 A	36.11 A	36.00 A	128.44 B	127.89 B
P_1		12.56 A	12.22 A	25.55 A	23.89 A	36.22 A	35.67 A	129.56 A	128.33 A
P_2		12.44 A	12.40 A	25.44 A	24.78 A	36.34 A	36.11 A	129.44 A	128.33 A
P_3		11.89 A	11.77 A	25.56 A	25.22 A	36.00 A	36.11 A	129.00 A	128.00 A
	P_1	13.33 a	12.67 a	24.33 a	23.00 a	35.67 a	35.00 a	128.67 a	127.67 a
N_1	P_2	13.00 a	13.00 a	25.33 a	24.33 a	36.34 a	36.33 a	129.33 a	128.33 a
	P_3	13.00 a	11.66 a	25.67 a	25.66 a	36.00 a	36.33 a	131.00 a	130.00 a
	P_1	12.00 a	12.00 a	25.33 a	24.66 a	37.00 a	36.00 a	130.67 a	129.00 a
N_2	P_2	13.00 a	13.00 a	26.00 a	25.00 a	36.33 a	36.00 a	130.00 a	128.00 a
	P_3	11.33 a	11.33 a	25.33 a	25.33 a	36.00 a	36.00 a	129.00 a	128.33 a
	P_1	12.00 a	11.97 a	24.00 a	24.00 a	36.33 a	36.00 a	129.33 a	128.67 a
N_3	P_2	11.67 a	11.33 a	25.00 a	25.00 a	36.33 a	36.00 a	129.00 a	128.67 a
	P_3	12.33 a	12.30 a	25.66 a	24.67 a	36.00 a	36.00 a	127.00 a	126.67 a
F value	N	1.16ns	0.86ns	1.00ns	0.48ns	0.42ns	0.05ns	9.80*	5.20*
F value	P	1.13ns	1.10ns	2.86ns	3.15ns	0.35ns	0.45ns	0.30ns	0.15ns
F value	N×P	1.35ns	1.75ns	0.69ns	0.87ns	0.65ns	0.47ns	2.03ns	2.19ns

Similar letters are not significantly different by LSD at $P < 0.05$. ns; non-significant, * and ** significant at $P < 0.05$ and $P < 0.01$, respectively.

Treatment N_3 made the peanut plants to reach flowering in minimum days as compared to other treatments during both years whereas for P minimum days to reach flowering in 2016 were seen in P_2 and for 2017 were seen in P_1 (Table 3). The interactive effect for treatments was also non-significant and the values for days to flowering were higher among all interactions but the highest interactive effect was seen in N_2 with P levels because the values for days to flowering higher in them as shown in Table 3.

Peanut cultivar reached to maximum pegging a bit late in 2016 study year as compared to 2017 among all the individual treatments of N and P. During growth season of 2016, maximum days to pegging were in N_2 treatment with value of 36.44 days whereas for 2017 it was also highest in same treatment with value of 36.00 days. Related to P, the average days to pegging were higher than seen among N treatments and highest days to pegging values for both seasons 2016 and 2017 were seen in P_2 viz. 36.34 days and 36.11, respectively. The interactive effect of treatments for both seasons regarding days to pegging was also non-significant. The N_2 interaction with P levels showed that the days to reach pegging were highest for both growing seasons whereas the N_1 interaction with P levels showed minimum days to reach pegging (Table 3). Overall, the peanut cultivar showed bit fewer days to maturity during the 2017 growing season as compared to 2016 among all treatments' levels of N and P. The days to maturity for both individual treatments' levels, as well as the interactive effect, varied significantly. For year 2016 and 2017, the minimum days to maturity were taken by peanut cultivar in N_3 ¬with values of 128.44 days and 127.89 days, respectively which were significant than other N levels' treatments. Whereas, for both seasons, highest days to maturity in N levels' treatments were reported in N_1. Different P levels didn't affect significantly as the plants among all levels of P reached to maturity by showing non-significant differences (Table 3). In the same way, the interactive effect of treatments was also non-significant for both seasons. So, overall, for germination, flowering, and pegging the treatments effects individually for N and P as well as for their interactions were non-significant, but for maturity, only in case of N treatments, the individual treatment effect was found significant. The average days to reach the peak of every growth stage were higher in 2017 than in 2016, minimum days were taken among these phases where the N and P were applied in N_3 level and P_3 level, respectively.

Table 3. Peanut yield and yield contributing traits as affected by nitrogen (N) and phosphorus (P) in both growing years.

Treatment		No. of Pods plant^{-1}		Weight of seeds plant-1 (g)		100 seed weight (g)		Aboveground Biomass (kg ha^{-1})		Pod yield (kg ha^{-1})	
Nitrogen		2016 A	2017	2016	2017	2016	2017	2016	2017	2016	2017
N1		59.94 A	58.46 A	32.24 A	31.73 A	45.12 B	45.34 B	8036.0 A	8014.1 A	2216.5 B	2205.4 B
N2		61.52 A	61.27 A	34.68 A	33.40 A	50.07 AB	50.67 AB	8057.9 A	8180.1 A	2549.7 A	2527.5 A
N3		58.61 A	57.34 A	31.65 A	31.84 A	54.21 A	53.54 A	9175.4 A	8842.0 A	2614.2 A	2647.4 A
P1		61.83 A	60.97 A	34.40 A	33.19 A	48.30 B	48.56 A	7011.7 A	6889.5 B	2225.6 B	2225.0 B
P2		63.72 A	62.47 A	33.29 A	32.35 A	49.52 AB	49.41 A	8777.6 A	8666.5 AB	2496.8 A	2507.7 A
P3		54.78 B	53.63 B	30.87 A	31.43 A	51.58 A	51.55 A	9480.2 A	9480.2 A	2658.1 A	2647.0 A
N1	P1	65.91 ab	64.91 a	34.68 a	34.38 a	43.33 a	43.33 c	6364 a	6297.0 a	1831.1 a	1830.0 a
	P2	58.41 c	57.58 c	29.95 a	29.41 a	43.86 a	44.20 bc	8773 a	8772.7 a	2398.8 a	2365.5 a
	P3	55.50 cd	52.90 cd	32.08 a	31.39 a	48.16 a	48.50 abc	8972 a	8971.7 a	2419.5 a	2419.0 a
N2	P1	60.25 abc	61.03 b	34.15 a	31.47 a	48.83 a	50.63 abc	7248 a	7280.9 a	2428.8 a	2428.3 a
	P2	62.75 abc	62.25 ab	35.02 a	33.74 a	50.03 a	50.33 abc	7610 a	7610.0 a	2580.0 a	2546.7 a
	P3	61.58 abc	60.55 b	34.88 a	34.97 a	51.36 a	51.36 abc	9316 a	9649.3 a	2640.3 a	2607.0 a
N3	P1	59.33 bc	56.96 c	34.38 a	33.71 a	52.73 a	51.70 ab	7423 a	7089.7 a	2511.4 a	2416.5 a
	P2	70.00 a	67.59 a	34.90 a	33.90 a	54.66 a	54.00 a	9950 a	9616.6 a	2416.8 a	2610.9 a
	P3	47.25 d	47.46 e	25.66 a	27.92 a	55.23 a	54.90 a	10153 a	9819.8 a	2914.5 a	2914.3 a
Fvalue	N	0.31ns	1.42ns	0.27ns	0.16ns	7.54*	6.22*	0.31ns	0.17ns	25.75**	11.52*
Fvalue	P	12.04**	13.34**	0.50ns	0.15ns	5.00*	1.88ns	2.86ns	4.57*	7.84*	19.96**
Fvalue	N×P	8.42*	7.14*	0.59ns	0.61ns	0.62ns	0.45ns	0.23ns	0.40ns	1.36ns	2.79ns

Similar letters are not significantly different by LSD at P <0.05. ns; non-significant, * and ** significant at P < 0.05 and P<0.01, respectively.

The influence of nitrogen and phosphorous on total dry matter was significantly varied between the seasons as mentioned in Figure 2. In both year, similar dry matter (DM) accumulation trends were observed in N applied treatments Figure 2 (a), (b). Initially, 30 DAS N2, N3 produced similar DM, but with the increase of growth of the plant, N_3 significantly increased DM production followed by N_2 and N_1 was quantified with lowest DM yield in both years. However, in case of P treatments, there were obvious difference between P application treatments and in both growing years. Start of growing season, 30 DAS there were non-significant differences among treatments. Later, significant dissimilarities were observed in P treatments, P2 and P3 had statistically equal influence on DM production and P1 produced less DM among them. Noticeably, P_2 and P_3 showed similar trend for DM production in 2016 Figure 2(c) but it changed in 2017 Figure 2(d), after 60 DAS P_2 significantly decreased DM production as compared to P_3, when it cross matched with previous year. Whereas P_1 quantified with lowest DM in both years.

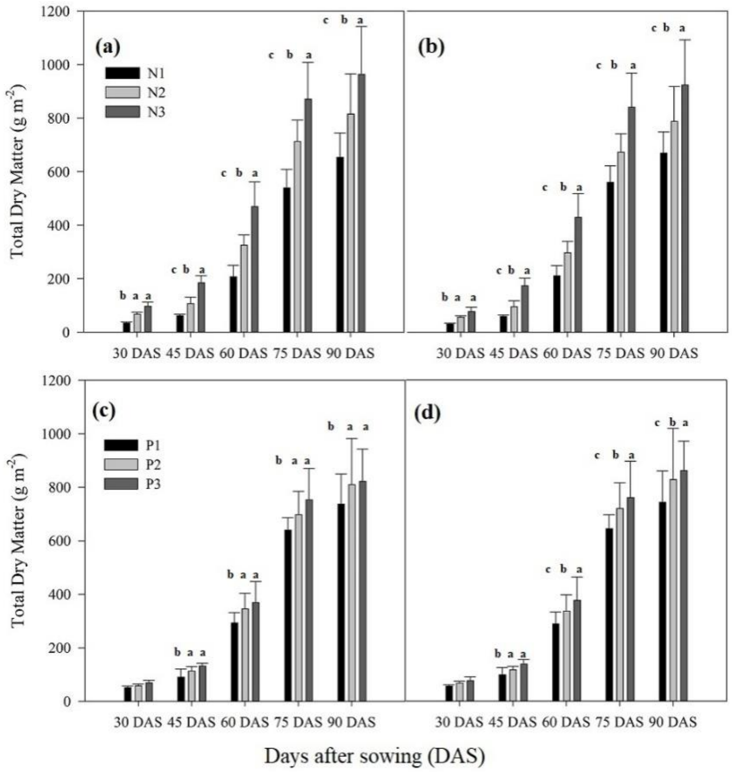

Figure 2. Total dry matter production (g m^{-2}) influenced by nitrogen (N) (a), (b) and phosphorus (c) (d) levels in 2016 and 2017 respectively.

Little differences in both years were induced by N treatments related to leaf area index (LAI). In 2016 smooth and increasing trend was observed with the following order N_3>N_2>N_1 Figure 3(a), similar order was also observed in 2017 but more fluctuations during the growth season Figure 3(b). Between both years no obvious differences were observed due to P application rate. Notably, LAI abruptly declined after 75 DAS collectively in P treatments. Whereas P_1 achieved more LAI followed by P_3 and lowest value was observed in P_2.

The yield parameters of peanut were greatly influenced due to the impacts of N and P levels which was totally different from the impacts on phenological parameters. Firstly, taking into consideration the number of pods per plant, it was noted that the values were higher in study year 2016 than 2017 and the difference was significant. The N_2 level of N treatment produced the highest number of pods per plant during both growing seasons of 2016 and 2017 with values of 61.52 and 61.27, respectively, given in Table. 3. But, the impact of all N levels on number of pods per plant was found non-significant during both years. In contrast, the impacts P levels on number of pods per plant was highly significant during both years under consideration. Highest number of pods per plant were found in P_2 treatment during both years 2016 and 2017 with values of 63.72 and 62.47, respectively (Table 3). The values of pods number were relatively low in P_3 during both growing seasons. Talking about the interactive effect of N and P, it was also significant, but the average values showed that the interaction of N_2 with all phosphorous levels produced relatively higher number of pods (Table 3).

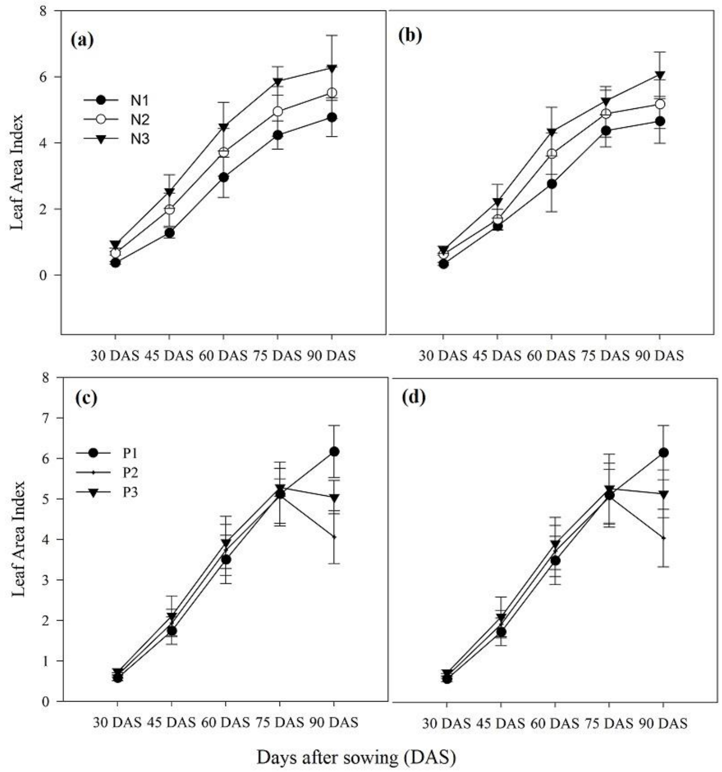

Figure 3. Leaf area index influenced by nitrogen (N) (a), (b) and phosphorus (c) (d) levels in 2016 and 2017 respectively.

Different levels of N and P had no significant effect on total weight of peanut seeds per plant (g). The values for seeds' weights were comparatively higher in 2016 than in 2017 but the individual impact of treatments of N, P and their interactive effect was non-significant, as shown in Table 3. On an average basis, N_2 level of N and P_2 level of P produced weighed seeds of peanuts in both growing seasons. The case for unit grain weight (g) was kind of interesting. Regarding N, the impact of N levels on peanut's unit grain weight (g) was significant during both years but for P, the impact was significant in 2016 but non-significant in 2017. For N_1 and N_2, the unit weight was relatively lower in 2016 and enhanced in 2017 but the impact for N_3 it was entirely opposite (Table 3). Overall, highest values during both seasons of 2016 and 2017 were found in treatment N_3 with values of 54.21 g and 53.54 g, respectively (Table 3). Same trend was seen regarding the impact for P levels on unit grain weight of peanut. Highest values were found in P_3 treatment but in 2017 the impact was non-significant among all P levels. The interaction of N and P also had a significant effect on the unit grain weight of peanut. On comparative basis, the interaction of N_2 with all P levels had a significantly higher unit weight producing effect on peanut among all treatments' interactions, as given in Table 3.

Total aboveground biomass (kg ha^{-1}) didn't influence by N levels during both years but P levels significantly impacted on it in 2016 as well as in 2017. The total biomass values were highest in N_3 level of N application during both years of 2016 and 2017 viz. 9175.4 kg ha^{-1} and 8842.0 kg ha^{-1}, respectively, given in Table. 3. In other N treatments the values were comparatively less. Most likely, same trend was seen in P treatments, where highest values were found in P_3, and minimum values were noted in P_1 (Table 3). Focusing the interactive effect of N and P on total aboveground biomass (kg ha^{-1}), it was observed that the impact was non-significant among all levels of N and P interactions as shown in Table 3.

The final pod yield (kg ha^{-1}) was greatly influenced by the N levels as well as the P levels, as there were significant pod yield differences among treatments. For N levels' treatments, highest peanut pod yield was found in N_3 during both calendar years of 2016 and 2017, with values of 2614.2 kg ha^{-1} and 2647.4 kg ha^{-1}, respectively, whereas minimum values were found in N_1 (Table 3). For N_1 and N_2, the yield decreased in 2017 as compared to 2016 but for N_3 the trend was opposite. For P applied treatments, the trend was opposite to N, as for N the impact was highly significant in 2016 and significant in 2017, shown in Table. 3. If the interactive effect of N and P is considered, then it was noted that their interaction also influenced the pod yield (kg ha^{-1}) significantly. On an average basis, comparatively higher pod yield values were found due to the interactive effect of N_3 with different P levels, as noted in Table 3. So, it was concluded that different levels of N and P application and their interactive effects as well impacted the growth and yield of peanut significantly.

Before and after two-year short experiment, there was an obvious difference of N contents in the upper soil (0-15 cm) depth. Two-year cultivation of peanut with varied application rate of N increased soil N contents regardless of N application rate. It clarifies that over and under application rate of inorganic N in peanut cannot increase soil N contents in upper soil surface in short time period. Almost double (0.4 g kg^{-1}) N increment was observed in all variable treatments in the study Figure 2. Whereas, differences in term of available phosphorus contents were not significantly changed, that might be due to the complex P availability phenomenon (Vance *et al.,* 2003).

Peanut phenological stages were not influenced by the combined effect of N and P in both growing years, however, physiological maturity was statistically different in response to N fertilizer application rate. Our results revealed that N1 augmented physiological maturity time in the semi-arid environmental conditions of Pakistan. This might happen due to late environmental and soil nutrient conditions as clarified by (Sepehri and Shahbazi 2017). Moreover, (Sepehri and Shahbazi 2017) argued that inorganic fertilizer application does not affect plant growth development and phenology, mainly environmental conditions are main driving factors for these changes. For yield and yield contribution traits, number of pods $plant^{-1}$, individually influenced by P application and significantly affected by interaction of N and P, it clarifies that low rate of N and P significantly increased pod production in plants that reduced with increasing rate of N and P application except in the case of N_3 and P_2 in both years. More importantly, increased number of pods were quantified with the lower 100-seed weight, but the interaction was statistically no significant (P>0.05). In 2017, aboveground biomass is significantly affected by P application. Individually, N and P had influence on pod yield production and increasing trend with increase application rate was observed, but their combined effect was statistically non-significant Table.3. Similarly, (Rajitha *et al.,* 2018) also argued that foliar or soil based application of nutrients increased pod production in peanut. These results supported our findings.

The variation in soil N and P levels were contributed by year practice (peanut cultivation and inorganic fertilizer application). Our results exhibited that collectively peanut cultivation and N application increment in N content in soil is about 80% in short term experimental duration, Whereas P application had not role in N increment in upper soil surface, while some dissimilarities were due to experimental error (8-10%), and remaining variations in N accumulation were contributed by other edaphic and environmental factors Figure 5. While in case of P soil variations, mainly were due to experimental error (sampling, analysis and calculations), different changes were induced by P application, between year practices and other contributing factors at the rate of 10,13 and 7 % respectively. Noticeably, in P increment variations were also contributed by N application to some extent. Wang *et al*., (2010) reported different results for P increment, these results explored that inorganic P application increased available P contents in soil and remaining P attached with other trace elements and metal ions in long term experiment. But here we clarified that our results were from short term experimental duration Figure 5.

In this study, we tried to evaluate the combined effect of N and P application rate on peanut phenology, yield, yield contributing traits and soil nutrient status. Two-year experimental results revealed that N and P had no obvious influence on peanut phenology but yield and yield contributing traits significantly (P>0.05) influenced by N and P application. Moreover, higher application rate of N and P increased peanut yield, but combined effect was non-significant. Similarly, two-year cultivation of peanut and N, P application enhanced N status of upper soil (double increment as compared to the start of the experiment) regardless of N application rate. However, P increment was not observed in the upper soil surface instead of varied P application rate that might be due to complex phenomena of P regulation in soil. In conclusion, a higher N and P application rate can be used to get a higher yield of peanut but that is more related to the soil and environmental conditions of the growing site for better utilization of resources. But we recommend long-term research in this area for a better understanding of this complexity.

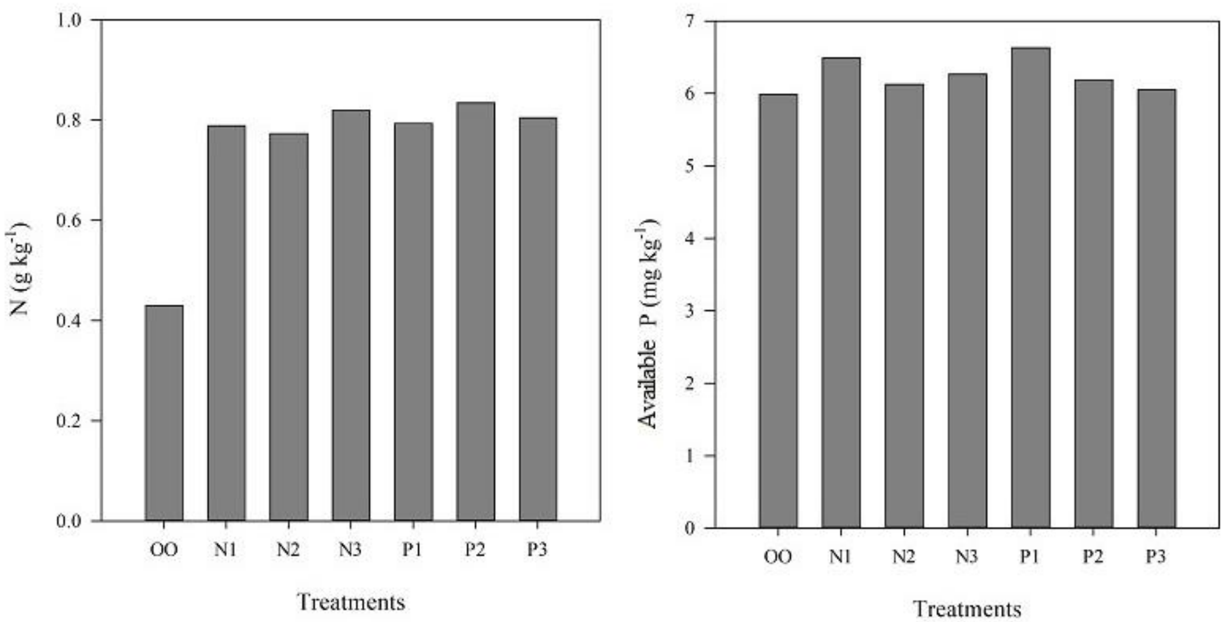

Figure 4. Soil nutrient status of total nitrogen (N) and available phosphorus (P) before (OO) after experimental treatments.

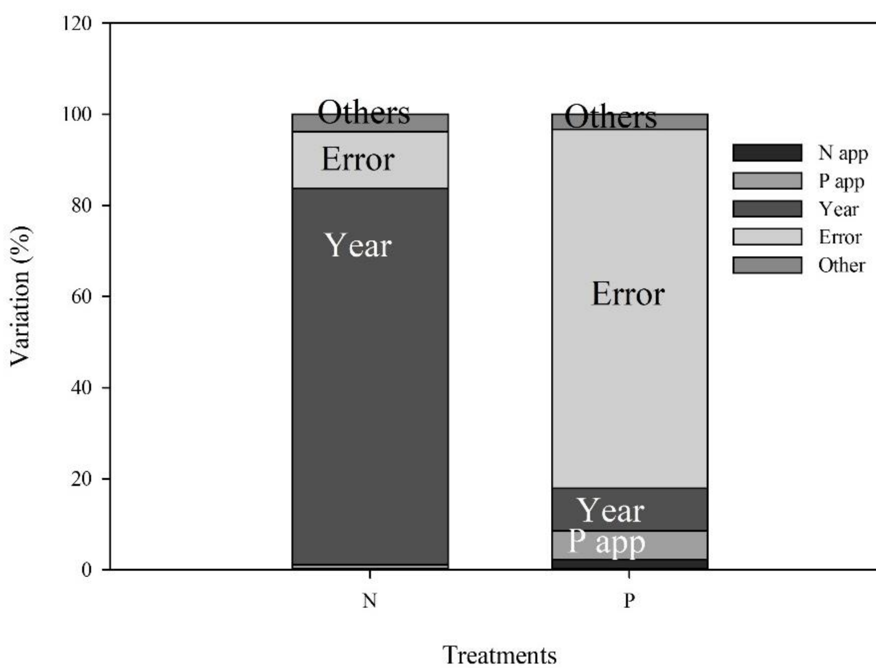

Figure 5. Variations driven by different factors in soil nitrogen (N) and available phosphorus (P) over experimental years.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Asiedu, R. and Sartie, A., 2010. Crops that feed the world 1. Yams: Yams for income and food security.

Biosci, I.J., Amba, A.A., Agbo, E.B., Garba, A., 2013. Effect of nitrogen and phosphorus fertilizers on nodulation of some selected grain legumes at Bauchi, Northern Guinea Savanna of Nigeria. Int. J. Biosci. 3, 1–7. https://doi.org/10.12692/ijb/3.1s0.1-7

Bogino, P., Banchio, E., Rinaudi, L., Cerioni, G., Bonfiglio, C., Giordano, W., 2006. Peanut (Arachis hypogaea) response to inoculation with Bradyrhizobium sp. in soils of Argentina. Ann. Appl. Biol. 148, 207–212. https://doi.org/10.1111/j.1744-7348.2006.00055.x

Carter, M.R., 1993. No Title, Soil Sampling and Methods of Analysis. Lewis Publishers, Boca Raton, FL.

Chirwa, M., Peter Mrem, J., Wilson Mta, P., Kaaya, A., Isaac Lung, O., 2016. Yield Response of Groundnut (Arachis hypogaea L.) to Boron, Calcium, Nitrogen, Phosphorus and Potassium Fertilizer Application. Int. J. Soil Sci. 12, 18–24. https://doi.org/10.3923/ijss.2017.18.24

Dello Jacovo, E., Valentine, T.A., Maluk, M., Toorop, P., Lopez del Egido, L., Frachon, N., Kenicer, G., Park, L., Goff, M., Ferro, V.A., Bonomi, C., James, E.K., Iannetta, P.P.M., 2019. Towards a characterisation of the wild legume bitter vetch (*Lathyrus linifolius* L. (Reichard) Bässler): heteromorphic seed germination, root nodule structure and N-fixing rhizobial symbionts. Plant Biol. 21, 523–532. https://doi.org/10.1111/plb.12902

FAO, 2009. Food Security and Agricultural Mitigation in Developing Countries: Options for Capturing Synergies, Food Security and Agricultural Mitigation in Developing Countries: Options for Capturing SynergiesFood and AgricultureOrganization of theUnited Nations.

Guzman, J.G., Ussiri, D.A.N., Lal, R., 2019. Soil physical properties following conversion of a reclaimed minesoil to bioenergy crop production. CATENA 176, 289–295. https://doi.org/10.1016/j.catena.2019.01.020

Halder, D., Panda, R.K., Srivastava, R.K., Kheroar, S., 2017. Evaluation of the CROPGRO-Peanut model in simulating appropriate sowing date and phosphorus fertilizer application rate for peanut in a subtropical region of eastern India. Crop J. 5, 317–325. https://doi.org/10.1016/J.CJ.2017.02.005

Hirel, B., Le Gouis, J., Ney, B., Gallais, A., 2007. The challenge of improving nitrogen use efficiency in crop plants: towards a more central role for genetic variability and quantitative genetics within integrated approaches. J. Exp. Bot. 58, 2369–2387. https://doi.org/10.1093/jxb/erm097

Khaliq, T., Gaydon, D.S., Ahmad, M.-D., Cheema, M.J.M., Gull, U., 2019. Analyzing crop yield gaps and their causes using cropping systems modelling–A case study of the Punjab rice-wheat system, Pakistan. F. Crop. Res. 232, 119–130. https://doi.org/10.1016/j.fcr.2018.12.010

Lal, R., 1997. Long-term tillage and maize monoculture effects on a tropical Alfisol in western Nigeria. I. Crop yield and soil physical properties. Soil Tillage Res. 42, 145–160. https://doi.org/10.1016/S0167-1987(97)00006-8

Martínez, L., Caballero-Mellado, J., Orozco, J. and Martínez-Romero, E., 2003. Diazotrophic bacteria associated with banana (Musa spp.). *Plant and Soil*, *257*, pp.35-47.

Magadlela, A., Vardien, W., Kleinert, A., Dreyer, L.L., Valentine, A.J., 2015. The role of phosphorus deficiency in nodule microbial composition, and carbon and nitrogen nutrition of a native legume tree in the Cape fynbos ecosystem. Aust. J. Bot. 63, 379. https://doi.org/10.1071/BT14216

Murphy, J., Riley, J.P., 1962. A modified single solution method for the determination of phosphate in natural waters. Anal. Chim. Acta 27, 31–36. https://doi.org/10.1016/S0003-2670(00)88444-5

Naab, J.B., Mahama, G.Y., Yahaya, I., Prasad, P.V. V., 2017. Conservation Agriculture Improves Soil Quality, Crop Yield, and Incomes of Smallholder Farmers in North Western Ghana. Front. Plant Sci. 8, 996. https://doi.org/10.3389/fpls.2017.00996

Naeem-ud-Din, Tariq, M., Naeem, M.K., Hassan, M.F., Rabbani, G., Mahmood, A., Iqbal, M.S., 2012. Development of Bari-2011: A high yielding, drought tolerant variety of groundnut (Arachis hypogaea L.) with 3-4 seeded pods. J. Anim. Plant Sci. 22, 120–125.

Pin, T., Schiller, J.M., 2016. Peanut Yield and Changes of

Soil properties by Intercropping in Upland Cropping Systems of Southeast Cambodia. Int. J. Environ. Rural Dev. 1, 128–133.

Rajitha, G. Reddy, M.S.B. and P.V.R., 2018. Yield and uptake of primary nutrients by groundnut (Arachis hypogaea L.) as influenced by foliar spray of secondary and micronutrients. Crop Res. 53, 230–232. https://doi.org/10.31830/2454-1761.2018.0001.24

Sepehri A and Shahbazi H, 2017. Effect of planting date and biological and chemical fertilizers on phenology and physiological indices of peanuts. Iran. J. F. Crop. Res. 15, 216–230.

Vance, C.P., Uhde-Stone, C., Allan, D.L., 2003. Phosphorus acquisition and use: critical adaptations by plants for securing a nonrenewable resource. New Phytol. 157, 423–447. https://doi.org/10.1046/j.1469-8137.2003.00695.x

WANG, J., LIU, W.-Z., MU, H.-F., DANG, T.-H., 2010. Inorganic Phosphorus Fractions and Phosphorus Availability in a Calcareous Soil 21-Year Superphosphate Application. Pedosphere 20, 304–310. https://doi.org/10.1016/S1002-0160(10)60018-5

Watson, C.A., Reckling, M., Preissel, S., Bachinger, J., Bergkvist, G., Kuhlman, T., Lindström, K., Nemecek, T., Topp, C.F.E., Vanhatalo, A., Zander, P., Murphy-Bokern, D., Stoddard, F.L., 2017. Grain Legume Production and Use in European Agricultural Systems. Adv. Agron. 144, 235–303. https://doi.org/10.1016/bs.agron.2017.03.003

Zahran, H.H., 1999. Rhizobium-legume symbiosis and nitrogen fixation under severe conditions and in an arid climate. Microbiol. Mol. Biol. Rev. 63, 968–89, table of contents.