Phenology and seed yield of okra (Abelmoschus esculentus (L) Moench) as influenced by Nitrogen and Phosphorus fertilizer rates in Pawe District, Northwester Ethiopia

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Abstract: A field experiment was conducted at Pawe Agricultural Research Center during the main rainy season of 2018 to evaluate the effects of nitrogen and phosphorus fertilizer rates on phenology and seed yield of okra. The experiment was laid out in randomized complete block design with three replications in factorial arrangement. Urea and triple superphosphate (TSP) used as a source of nitrogen and phosphorus, respectively.Plant height, leaf number per plant, primary branch number per plant and 50% flowering date were significantly affected by nitrogen and phosphorus fertilizer applications. Date of 50% emergence dry pod length and width were not significantly affected by nitrogen and phosphorus fertilizer rates. Significant responses were also observed in seed yield and related traits of okra due to nitrogen and phosphorus fertilizer application.Maximum pod number per plant (20 and 19.67) were recorded from treatment received at the rate of 0 and 75 and 50 and 37.5 kg/ha N and P, respectively. Similarly maximum number of seeds per pod (93.47) were recorded from N and P treatment at the rate of 0 with 112.5 kg/ha. The highest 1000 seed weight (80.83 gm) were obtained from the combinations of N and P at the rate of 50 with 75 kg/ha. Yield is the result of these mentioned traits and significantly maximum yield (659.01 kg/ha) were recorded from N and P treatments at the rate of 0 with 75 kg/ha. It is possible to conclude that application of N and P at the rate of 0 with 75 kg/ha gives economical optimum amount of seed yield of okra in the study area.

Keywords: Nitrogen, Okra, Phenology, Phosphorus and Seed yield

Introduction

Vegetable crops are very vital due to their advancedyield potential, higher return and high nutritional value and suitability for small land holding farmers.Okra (*Abelmoschus esculentus* (L.) Moench) is an important warm season fruit vegetable crop of the tropical and subtropical regions of the world. It is originated from Abyssinian center of origin(Meena et., 2018).It is rich sources of vitamins, calcium, potassium, and other minerals and a mucilaginous preparation from the pod can be used as a blood plasma replacement(Muqtadir et al., 2019).In Ethiopia, it has been grown for its edible green pods which can be used as fresh, canned, or dried food in some parts of the country like Humera, Benishangul gumz and Gambela region. There is no available record about the production area coverage and productivity of the crop in Ethiopia. However, it was considered as the third most important crop next to sorghum and maize in Gambela region (Baw et al., 2017).It is also highly important in Benishangul Gumuz and highly preferred &consumed by the native people(Shambel et al., 2020).Farmers grow the crop around their homestead devoid of any more cultivation and nutrient application except animal manures which was collected from their cattle. No attention has so far been given for the improvement ofokra production like spacing and fertilizer application weed and insect pest control to increase the productivity of the crop under Ethiopian condition.

The seed is the prime factor that determines the quantitative and qualitative characteristics of the crop that is going to be harvested later on(Feleafel, 2005).Providing good quality seeds is also one of the most important and easiest means to accelerate the productivity of vegetable.As is well known, vegetable seed production is unorganized sector (farmer's own saved seeds) and unavailability of quality seed and heavy incidence of biotic stresses are the most important reasons for low yield(Chattopadhyay et al., 2011). There is need to harness the potential by improving the quality of seed at par with international seed quality standards.Therefore; more attention must be directed towards increasing seed yield with good quality.

Nutritional imbalancesin the soil cause instability in productivity &hidden hunger ofnutrient besides resulting in poor nutritional quality of vegetable.The nutrient requirements of crops depend upon soil texture, types of previous vegetation cover, cropping intensity and soil moisture (Khan et al., 2013). Fertilizers are generally applied to improve the crop yield, nutritional quality and aesthetic value of crops (Sikander et al., 2009). Nitrogen and phosphorus is often described as the two most important limiting nutrients in crop production.Fertilization, in general and particularly with nitrogen (Feleafel, 2005)and phosphorus, is considered as one of the major factors that greatly affect seed yield and quality of okra(El-Waraky, 2014).Hence, among the several factors affecting phenology, growth and seed yield of okra, nutrition especially nitrogen and phosphorus play an important role in okra seed production and need to be studied more precisely. Therefore, the present study was initiated to find out the economical optimum level of nitrogen and phosphorus for achieving the highest seed production with good quality in okra plants.

Materials and Methods

The experiment was conducted at Pawe Agricultural research center during rainy season of 2018. The experimental site is located within latitude 11^{0}18`49.6``N and longitude 036$^{0}$24`29.1``E, which is found in Benshangul Gumuz regional state in Metekel Zone. Climatic conditions and soil structure characteristics of the experimental site are presented in Table 1 and Table 2 respectively. The altitude of the area is 1120 meter above sea level. The experiment treatments consisted of four different level of N (0, 50, 100, 150) and four level of P_2O_5 (0, 37.5, 75 and 112.5) kg/ha. The treatments were arranged in a randomized complete block design (RCBD) with three replications in factorial arrangement.The entire amount of TSP in the experiments was applied at the time of final land preparation. Urea was applied in two equal installments as top dressing. First and second round Urea applications were practiced as top dressing around the plant and incorporate with soil at 3rd and 5th week after seedling emergence.All recommended cultural practices and plant protection measures were followed throughout the experimental period. Phenological parameters (date of emergence and date of 50% flowering), growth parameters (plant height leaf number and number of branches per plant) and yield related parameters (number of pod per plant, dry pod length and width, number of seeds per pod 1000 seed weightand seed yield) were recorded from randomly selected five plants based on the standard procedures.

Table 1. Metrological information

Month	Rain fall	Minimum T^{o} c	Maximum T^{o} c	Relative humidity
January	0	12.6	34.4	66
Feb	0	16.7	38	64
March	0	17	38.2	60
April	0	18.5	38	65
May	170.7	19.8	37	65
June	315.7	19	29.9	86
July	338.2	18	28.8	86
August	339.9	17.7	28.6	89
September	131	17.7	30.1	87
October	142.2	17.8	30.5	86
November	70	15.9	32.3	85
December	0	14.9	33.4	83

Source: Ethiopian Institute of Agricultural Research Agro-meteorological Service

Table 2. Soil physicochemical properties

Soil parameters	Values
pH	5.24
Organic matter (%)	4.10
Organic carbon (%)	2.38
Total nitrogen (%)	0.186
Available P (mg/kg)	1.81
Sand (%)	2
Silt (%)	20
Clay (%)	78

Class	Clay

Result and discussion

Effect of Nitrogen and Phosphorus Fertilizer Rates on Phenological Parameters of Okra

The result of the studyrevealed that both the main factors and their interaction effects had no significant effect on days to emergence (Table 3). The possible reason could be that, germination process is mainly controlled by viability of seed, adequate moisture, proper temperature, good aeration, freedom from pathogenic organisms and toxic amount of salts and least by soil fertility. Therefore, the effect of fertilizers was not pronounced at the initial stage of germination. This result agreed with that of Khan et al., (2000) who reported that different levels of nitrogen alone and in combination with constant doses of phosphorus and potassium had no significant effect on days to emergence of Okra.

Days required to 50% flowering significantly influenced by the main factor nitrogen and phosphorus and their interaction (Table 3). The control plot had resulted in the shortest period (60.33 days) for 50% flowering followed by treatment that received phosphorus alone with a level of 112.5 kg/ha (61.0 days) (Table 4). The longest days (64.0 days) for 50% flowering were recorded from treatment received N and P_2O_5 at a rate of 100 and 112.5 kg/ha, respectively. Regarding nitrogen fertilizer treatments, the higher doses of N delayed blooming.This is due to the fact that higher rate of N normally encourages vegetative growth dominating reproductive phase. Phosphorus enhances development of reproductive parts that stimulates blooming and fruit setting, therefore minimum days to flowering were recorded in plots fertilized with lowest or nil dose of N combined with phosphorus. The result was in line with the report of (Khan et al., 2013) who recorded maximum days to flowering (41.11) from the treatment levels of 150 kg N and 120 kg P/ha and minimum days to flowering (33.11) from the control or not fertilized plots.

Table 3. Mean square values for selected phenology and growth parameters

Source of Variation	DF	DE	DFL	PH	LN	BN
Block	2	0.08^{ns}	1.64^{ns}	605.25***	7.69^{ns}	0.065^{ns}
Nitrogen	3	0.83^{ns}	7.74***	1205.6***	45.2***	0.2^{ns}
Phosphorus	3	0.16^{ns}	2.29*	116.15*	22.42**	0.5**
N*P	9	0.59^{ns}	1.93**	60.39ns	7.42*	0.36**
Error	30	0.24	0.62	37.97	16.77	0.072
CV		9.02	1.26	5.55	9.5	16.48

DF=degree of freedom, DE= data of emergence, DFL= 50% flowering date, PH=plant height, LN= leaf number, BR= branch number, N*P= interaction of nitrogen and phosphorus

Table 4. Interaction effects of N and P on selected Phenological and growth parameter

Treatment combination	**Plant height** (cm)	**50 % flowering date**	**Primary branch number**	**Leaf number per plant**
N1P1	94.13	60.33^{g}	1.33^{c-e}	15.93^{f-i}
N1P2	99.8	61.33^{e-g}	1.46^{cd}	16.4^{e-i}
N1P3	99.47	61.67^{d-g}	2.1^{ab}	16.6^{d-i}
N1P4	98.2	61^{fg}	1^{e}	14.2^{i}
N2P1	120.67	61.33^{e-g}	1.33^{c-e}	18.53^{b-g}
N2P2	123.2	63.67^{ab}	2.27^{a}	23.67^{a}
N2P3	124.67	63^{a-d}	1.67^{b-d}	20.4^{bc}
N2P4	120.8	62^{c-f}	1.73^{bc}	19.47^{b-d}
N3P1	106.13	61.67^{d-g}	1.4^{c-e}	15.53^{hi}
N3P2	108.8	62.67^{a-e}	1.6^{cd}	20.2^{bc}
N3P3	110.0	63^{a-d}	1.67^{b-d}	17.67^{c-h}
N3P4	121.6	64^{a}	2.23^{a}	20.73^{b}
N4P1	104.53	63.33^{a-c}	1.27^{de}	15.53^{g-i}

N4P2	115.8	63^{a-d}	1.6^{cd}	18.67^{b-f}
N4P3	118.73	62.33^{b-f}	1.73^{bc}	19.6^{bc}
N4P4	10.8	62^{c-f}	1.67^{b-d}	18.93^{b-e}
LSD (at 5 %)	14.25	1.38	0.48	2.89
CV	5.5	1.26	16.48	9.5

Means sharing the same letter in the same columns or does not have any letter does not have a significant difference, N1= nitrogen at 0 rate, N2= nitrogen at 50kg/ha, N3=nitrogen at 100 kg/ha, N4= nitrogen at 150 kg/ha, P1=phosphorus at 0, P2= phosphorus at 37.5 kg/ha, P3= phosphorus at 75 kg/ha P4=phosphorus at 112.5 kg/ha

Table 5. Main effects of N and P on selected growth parameters

Nitrogen rate Kg/ha	Plant height (cm)	Primary branch number per plant	Leaf number per plant
0	97.9^{c}	1.47^{ab}	15.78^{c}
50	122.33^{a}	1.75^{a}	20.52^{a}
100	111.65^{b}	1.72^{a}	18.53^{b}
150	111.97^{b}	1.57^{ab}	18.23^{b}
Phosphorus rate Kg/ha			
0	106.36^{b}	1.33^{b}	16.43^{b}
37.5	111.92^{a}	1.73^{a}	19.73^{a}
75	113.22^{a}	1.79^{a}	18.57^{a}
112.5	112.35^{a}	1.65^{a}	18.33^{a}
LSD (at 5 %)	5.138	0.22	1.44
CV	5.55	16.48	9.5

Mean values sharing the same letter in the same columns or does not have any letter does not have a significant difference

Effects of nitrogen and Phosphorus fertilizer rates on growth parameters of okra

Analysis of data showed thatapplication of nitrogen and phosphorus had a significant effect on plant height and number of leavesper plant (Table 3). Branch number per plant was affected only by main factor phosphorus fertilizer. Like the main factor nitrogen and phosphorus, the interactioneffects showed a significant on number of leaves and numbers of branches per plant.None significant differences were observed due to interaction effect of nitrogen and phosphorus levels on plant height at final harvest. The experimental results revealed that maximum plant height (122.33 cm) was recorded from treatment pot received 50 kg/ha nitrogen, while the minimum plant height (97.90 cm) was recorded from the control plot.The highest plant height (113.22 cm) recorded from treatment received P_2O_5 at a rate of 75 kg/ha. All rates of P_2O_5 significantly increased plant height over the control plot but produced statistically identical result compared with each other (Table 5).Significantly higher number of leaves per plant (23.67)were recorded from a combined application of 50 kg/ha N together with 37.5 kg/ha P_2O_5 (Table 7).Application of N and P_2O_5at the rate of 50 with 37.5, 100 with 112.5 and 0 with 75kg/ha produced maximum number of branches per plant 2.27, 2.23 and 2.1 respectively (Table 6). This is because nitrogen is thefundamental part of the chlorophyll molecule and essential in the formation of amino acids, which are the building blocks of all proteins including the enzymes, which control virtually all biological processes. Besides, phosphorus stimulates cell division, elongation as well as flowering and fruit set.

Effects of Nitrogen and Phosphorus fertilizer rates on seed yield of Okra

Pod number per plant

The number of pod per plant varied from 12.1 to 20.6 due to different rates of N and P fertilizers application as shown in Table 7. Results pertaining to the number of dry pod per plant depicted that maximum number of podswere recorded from the rate of 0 kg N and 75 kgP_2O_5/ha and 50 kg/ha N and 37.5 kg/ha P_2O_5. The lowest number of pods per plant (12.1) were recorded from 50 kg/ha N with nil dose of phosphorus.These results are in linewith Sajid et al., (2012) who found thatmaximum amount of pod number per plant recorded from the highest rate of N and P combinations.The uppermost number of pods plant might be due to vigor of plant, more number of leaves and additional number of branches per plant by the application of nitrogenous and phosphorus fertilizer together, while less number of pods per plant might be due to the poor nutritional status of control plots (Khan et al., 2000).

Dry pod length and width of Okra

Dry pod length and width of okra were not significantly affected by main factor nitrogen and phosphorus fertilizers. Only dry pod length was significantly affected by the interaction effects of N and P_2O_5 application (Table 8).The maximum and minimum dry pod length (34.33 cm and 21.5 cm) recorded from the interaction effects of N and P_2O_5at the rate of 50 and 37.5 kg/ha and from the control, respectively (Table 9). The result agrees with Khan et al., (2000) who reported that maximum pod length recorded from the combination of NPK at the rate of 120-90-60 kg/ha and the minimum values from the control plot.

Table 6. Mean square values for yield related traits

Source of Variation	DF	PNPP	DPL	DPW	SNPP	1000 SDW	SYD
Block	2	12.2*	22.23ns	0.0007ns	10.06ns	1.75ns	6384.64ns
Nitrogen	3	5.65*	15.02ns	0.045ns	367.58***	7.28**	33045.68***
Phosphorus	3	24.4***	18.39ns	0.0057ns	340.63***	45.06***	45174.24***
N*P	9	19.88***	25.4**	0.037ns	98.8***	3.77*	18977.54***
Error	30	2.41	7.86	0.038	12.38	1.44	2464.9
CV		10.38	9.68	8.53	4.7	1.54	11.62

Notice: DF= degrees of freedom, PNPP= Pod number per plant, DPL= dry pod length, DPW= dry pod width, SNPP= seed number per pod, 1000 SDW= 1000 seed weight, N*P= nitrogen and phosphorus interaction, CV= coefficient of variation and SYD= seed yield

Table 7. Interaction effects of N and P on seed yield related parameters

Treatment combination	**Pod number per plant**	**Dry pod length** (cm)	**Seed number per pod**	**1000 seed weight** (gm)	**Seed yield** (Kg/ha)
N1P1	12.77^{c-d}	21.5^{c}	75.4^{c-e}	75.0^{g}	380.63^{de}
N1P2	15.36^{bc}	30.0^{ab}	77.6^{bc}	78.33^{c-e}	450.44^{cd}
N1P3	20.6^{a}	29.88^{ab}	82.87^{b}	76.67^{e-g}	659.01^{a}
N1P4	15.06^{b-d}	30.22^{ab}	93.47^{a}	80.67^{a}	517.8^{bc}
N2P1	12.1^{e}	30.72^{ab}	59.46^{h}	75.0^{g}	283.62^{f}
N2P2	19.67^{a}	34.33^{a}	76.13^{cd}	79.5^{a-d}	557.06^{b}
N2P3	13.85^{b-e}	27.0^{b}	78.76^{bc}	80.83^{a}	400.05^{de}
N2P4	12.29^{de}	29.98^{ab}	76.9^{c}	80.16^{a-c}	349.89^{ef}
N3P1	14.92^{b-e}	30.98^{ab}	68.06^{fg}	75.67^{g}	398.2^{de}
N3P2	14.47^{b-e}	27.67^{b}	79.06^{bc}	76.67^{e-g}	442.8^{cd}
N3P3	15.21^{bc}	28.94^{b}	78.06^{bc}	77.16^{ef}	453.25^{cd}
N3P4	15.12^{b-d}	28.11^{b}	69.97^{ef}	78.5^{b-e}	398.63^{de}
N4P1	12.93^{c-e}	27.77^{b}	63.43^{gh}	75.33^{fg}	323.58^{ef}
N4P2	16.64^{b}	30.55^{ab}	77.1b^{c}	77.83^{de}	488.78^{bc}
N4P3	12.5^{c-e}	27.77^{b}	70.57^{d-f}	77.16^{ef}	339.71^{ef}
N4P4	15.97^{b}	27.72^{b}	66.03^{fg}	80.5^{ab}	387.86^{de}
LSD (at 5 %)	2.89	4.92	5.8	2.01	86.57
CV	10.38	10.22	4.69	1.55	12.19

Mean values sharing the same letter in the same columns or does not have any letter does not have a significant difference

Number of seeds per pod

Number of seeds per pod was significantly affected by both the main factor N and $P_2O_5$and their interaction (Table 6). Application of N from nil to the highest level tended to decrease the number of seeds per pod, but was not consistently affect by the N application rate (Table 8). The higher fruit in a plant contain a small number of seed with higher seed size.This might be due to the fact that application of N promotes luxuriant and succulent vegetative growth at the expense of the reproductive phase.Data in Table 8 indicates that phosphorus fertilization significantly increased seed yield per pod compared with the control plot although statistically at par when compared with each other.The obtained increments in the seed yield as a result of P_2O_5 application might be directly related to the functions of P in plant which enhances development of reproductive parts by stimulating blooming and fruit setting. Each plant has its own nutrient requirement for the development and functioning in its life. Further increment beyond its demand the nutrients will be loosed or fixed to be unavailable for the plant. So further application of P beyond 37 kg/ha in this study may not enhance the Okra seed production per pod. These results seemed to be in accordance with the reports of El-Waraky (2014) who reported that maximum number of seeds per pod (69.6) recorded from treatment received P_2O_5 at the rate of 45 kg/ha.The maximum seed number per pod (93.47) were recorded from treatments of P_2O_5 at the rate of 112.5 kg/ha with nil dose of N (Table 7). The lowest number of seeds per pod (59.46) were recorded from treatment plots that received N at the rate of 50 kg/ha alone. In contrary with this finding Khan et al., (2013) reported that N and P level at different rates did not influence the number of seeds per pod in different Okra varieties.

1000 seed weight

1000 seed weight significantly influenced only by main factor Phosphorus (Table 6). Application of nitrogen remained none significant among all treatments to1000 seed weight. The highest 1000 seed weight(79.96 gm)was recorded from treatment that received 112.5 kg/ha P_2O_5 whereas the lowest (75.25 gm) was recorded from the control plot (Table 8). While P_2O_5 treatments at the rate of 37.5 and 75 kg/ha did not gave statically detectable variation amongst each other.Increase in 1000 seed weight withincreasein phosphorus fertilization might be due to more mobilization of the metabolites, resulted in improved seed filling and better reproductive performance. The results are in agreement with(Amjad et al., 2001) who reported highest number of seeds per fruit and 1000-seed weight mean values at the highest phosphorus rate. Bhende et al., (2015) also reported that maximum seed weight was recorded from treatment plots received P at the rate of 75 kg/ha.

Table 8. Main effects of N and P on Yield and Yield related trait

Nitrogen rate Kg/ha	Pod NPP	DPL (cm)	DPW (cm)	SNPP	1000 SD(g)	Seed yield (kg/ha)
0	15.95^{a}	27.916^{b}	2.25	82.33^{a}	77.67^{b}	501.97^{a}
50	14.48^{b}	30.513^{a}	2.36	72.81^{b}	78.87^{a}	397.66^{b}
100	14.93^{ab}	28.929^{ab}	2.34	73.79^{b}	77.0^{b}	423.22^{b}
150	14.51^{b}	28.458^{ab}	2.24	69.28^{c}	77.71^{b}	384.98^{b}
Phosphorus rate Kg/ha						
0	13.18^{c}	27.75^{b}	2.27	66.59^{b}	75.25^{c}	346.51^{c}
37.5	16.54^{a}	30.64^{a}	2.29	77.47^{a}	78.08^{b}	484.77^{a}
75	15.54^{ab}	28.4^{ab}	2.298	77.57^{a}	77.96^{b}	463.0^{a}
112.5	14.61^{b}	29.027^{ab}	2.32	76.59^{a}	79.96^{a}	413.55^{b}
LSD (at 5 %)	1.29	2.33	0.16	2.9	1.002	41.39
CV	10.38	9.68	8.53	4.72	1.54	11.63

Mean values sharing the same letter in the same columns or does not have any letter does not have a significant difference

Seed yield per ha

Data presented in Table 7 showed that application of N and P_2O_5 had significant effect on okra seed production. The superior seed yield (659.01 kg/ha) recorded from 75 kg/ha P_2O_5 with nil dose of N which was closely followed byN and P_2O_5 treatment combination at the rate of 50 with 37.5 kg/ha and the lowest seed yield(323.58 kg/ha) were recorded from treatment plots received N at the rate of 150 kg/ha with nil dose of P_2O_5. Even if it was not consistence, both main factors nitrogen and phosphorus fertilizer hadinverse relationship in the case of seed yield (Table 8).These results seemed to be in accordance with those reported byEl-Waraky, (2014) who found that maximum seed yield of okra recorded from phosphorus fertilization at the rate of 45 kg/ha. Non-significant effects of nitrogen fertilizer rates on sound seed yield were also reported by Khan et al., (2013). The obtained increment in seed yield of okra mainly depends upon the pod number per plant, seed number per pod and 1000 seed weight, characteristics which vary with the genotype.

Conclusion

It can be concludedfrom the experiment that N and P applications at the rates of 50 with 37.5 kg/ha gives superior in primary branch number and leaf number per plantwhich is the growthattributing factorsas well as pod number per plant and dry pod length and non-significant differences were observed in days to emergence. Maximum seed number per pod were recorded from the application of N and P at the rate of 0 with 112.5 kg/ha and the highest 1000 seed weight recorded from N and P applications at the rate of 50 with 75 kg/ha. Based on thus yield contributing factors, the maximum seed yield of okra were obtained from N and P treatment applications at the rate of 0 with 75 kg/ha which is closely followed by 50 with 37.5 kg/ha.These two fertilizer rateswere found to be the best dose and are recommended for the highest seed yield of okra under rainfed conditions of Pawe.

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