ONION RESPONSE TO PHOSPHORUS FERTILIZER

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ABSTRACT: Onion (*Allium cepa* L.) is among the most important food plants with high nutritional value, but insufficient application of phosphorous is one of the constraints to the yields. Research on onion responses to different doses of phosphorus will optimize fertilizer dose, making the practice more competitive with less environmental effects. Three field experiments were carried out for two years to evaluate the effect of different phosphorus levels on the yield of onion in Randomized Complete Block Design (RCBD) with three replications and four treatments (80, 120, 160, and 200 Kg P_2O_5 ha^{-1}) along with N and K at a rate of 60 Kg ha^{-1}. From the results, it can be concluded that the onion responded to applied phosphorus doses and the variance analysis showed that the P effect was significant. The maximum (18.58 t ha^{-1}) onion bulb yield was obtained from a combination of NPK @ 60-200-60 Kg ha^{-1} and was appeared statistically equal to the yield (18.41 t ha^{-1}) obtained from NPK @ 60-160-60 Kg ha^{-1} which also found suitable, effective and economically viable for the cultivation of onions in Punjab, Pakistan.

Keywords: *Allium cepa* L., condiments, Economic analysis, Field Experiments, P_2O_5.

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INTRODUCTION

Onions are herbaceous biennial members of the Alliaceae family which are usually cultivated as annuals. Onion is one of the most essential condiments, usually used green or as a mature bulb or both and used to prepare a variety of dishes such as soups, sauces and food seasoning. Mild or colorful bulb onions are often selected for vegetables (Khan *et al*., 2005). Consumers also have very strong local preferences about onion size, shape and bulb (Nadia and Sidahmed, 2015). Pakistan is currently the world's seventh-largest onion producer (FAO, 2012), while China is the world's leading country. In the field of farmers, onion productivity varies from 9 to 15 t ha^{-1} that is considerably lower than the experimental yield i.e. 30-35 t ha^{-1} (Lemma and Shimeles, 2003). This may be attributed to several factors. Fertilizer application is one of the most important factors in onion production because it directly impacts growth and yield (Kurtz *et al*., 2013). Phosphorus deficiency (P) is one of the major crop growth constraints in many tropical soils due to reduced indigenous content and high P-immobilization (Abdisa *et al*., 2011). Phosphorus, due to low native content and high immobilization within soil, is one of the most complex in use in many soils. P is essential for rapid root development, a deficiency typically reduces the size of the bulb and delays maturation (Horneck, 2004; Brewster, 2008). As an essential nutritional element, phosphorus plays its part in controlling many plant physiological parameters, which in turn affects yield. One reality must be borne in mind, however, is that the P given to the plant or the soil is largely dependent on the available reservation of this element in the soil, so the negative or positive results could be due to this quantity or sources stored in the soil (Ristimuki *et al*., 2000). The response of onion to phosphorus fertilization depends on the genotype, soil P level, source P, soil and environment (Grant *et al*., 2005). Excessive use of inorganic nitrogen and phosphorus fertilizers leads to substantial growth with very little effects on yield and decay of bulbs (Diaz-Perez, 2003; Lee, 2012). Because of their shallow, unbranched root system, onions are more vulnerable to nutrient deficiencies than most other crops; therefore, they need and often respond well to fertilizer additions (Brewester, 1994). Increased phosphorus from zero to the highest in onion plants yielded the highest levels of dry weight (El-Hamady, 2017). Several authors reported that phosphorous application levels of up to 200 Kg P ha^{-1} maximized yields of onions (El-Rehim, 2000; Singh, 2000). Increased P levels also increase bulb size and number of sellable bulbs (Nagaraju, 2000). Similarly, in Ethiopia (Kebede, 2003), Phosphorous fertilization increased yield and bulb weight at 25 or 50 Kg ha^{-1}, even though soil analysis showed no nutrient deficiency. Different results were published, however, that P application did not significantly affect the yield of onions (Abdissa, 2011). Costa *et al*. (2009) documented onion response up to 90 Kg P ha^{-1}, obtaining a yield of 33.4 t ha^{-1}. Resende *et al*., (2016) reported higher yields for cultivars of onion: Franciscan IPA-10 and Vale Ouro IPA-11 at a dose of 132 Kg P ha^{-1}, analogous to the economic dose of 130 Kg P ha^{-1}. The use of 168.75 Kg P ha^{-1} produced maximum economic yield of bulbs, gross income, net income, yield rate and profitability of onions (Júnior, *et al*., 2016).

Onion is cultivated in many areas of Pakistan, but many constraints led to low yields. Due to the low natural P content and high immobilization, phosphorus deficiency and inadequate phosphorus usage are the main constraints in Pakistani soil for onion production. Recommendation rate for phosphorus fertilizer is still not well established. Therefore, farmers have lower onion yields. Towards this end, this study was undertaken to investigate the effects of different phosphorus fertilizer levels on onion yield.

MATERIALS AND METHODS

Three experiments were carried out at different sites, with a total of nine replications in three years on different farmers' fields in Randomized Complete Block Design (RCBD) to assess best suitable phosphorus rate for onions. The experiment consisted of 04 treatments. The nutrient levels of phosphorus (P) were 80, 120, 160 and 200 Kg ha^{-1}) along with N and K at a rate of 60 Kg ha^{-1}. Fertilizers, all phosphorus (as DAP diammonium phosphate), all potassium (as SOP potassium sulphate), and half nitrogen (as urea) were used during sowing. After 3-4 weeks of transplantation, the remaining one-half nitrogen (as urea) was applied. As per the Government's policy, all quality tested fertilizers were given free of charge to farmers and all other farm management practices were performed by farmers as per guidance by the department. Each treatment plot size was 1/40 of a hectare. Prior to sowing onion, the experimental fields were prepared following the farmers' traditional tillage practices. For the current study, Dark Red and Phulkara varieties were chosen. Field layouts were designed according to design requirements, and each treatment was randomly allocated to experimental plots. Composite representative surface soil samples (0-15 cm) were obtained randomly from each experimental sites using an auger before sowing. soil samples were air-dried and sieved with 0.02 mm sieve wire mesh and analyzed for EC, pH, Organic matter (Walkley and Black, 1934), available P (Olsen and Sommers, 1982) and exchangeable K (Brown & Warencke, 1988). All tube well water and canal water were used to irrigate the crops. At physiological maturity, when 70% of their leaves were damaged, plants were harvested and used to estimate yield for all treatments at a site on the same day from randomly selected plot (3 X 3 M^2) per treatment and packed directly for the fresh market. Gross margin of different fertilizer treatments for crops and fertilizer inputs was determined using the onion bulb yield from the two-year pooled data at an average market price of Rs. 37 Kg^{-1}. Data were subjected to analysis of variance. Differences between onion productivity treatments were analyzed by ANOVA using the "CoStat 6.451" statistical software. Partial budget analysis was used to assess the most economically acceptable dose of fertilizer for the recommendation. Detail of the initial soil characteristics is given in Table 1 before experimentation.

Table-1: Description of pre-sowing soil analysis, variety and previous crop.

Location	**Soil parameters and previous crop**							
	EC (dS m^{-1})	**pH**	**OM%**	**Available P (ppm)**	**Extractable K (ppm)**	**Texture**	**Previous crop**	**Onion variety**
					First Year			
Location-1	1.82	8.0	0.88	4.3	178	Loam	Fallow	Phulkara
					Second Year			
Location-2	2.04	8.3	1.29	7.4	140	Loam	Fallow	Phulkara
Location-3	2.36	7.5	0.83	8.8	210	Loam	Cotton	Phulkara

RESULTS

a. **Initial soil fertility analysis of the soil of the experimental sites.:** Table 1 shows the initial chemical properties, soil fertility status of the sites prior to the study, variety and previous crop. Three soils / sites used for research over two years were loamy textured, non-saline, alkaline in nature, low to medium in organic matter (OM), low in available P and optimum in exchangeable K. Sowing of all experiments is performed between December to January.

b. **Average NPK response to fresh bulb onion yield in two years:** Almost similar trends in onion bulb yields were observed in the two-years. As a result, individual and pooled analysis was carried out, the results are discussed below accordingly. The fresh bulb yield of onion was significantly affected by different doses of phosphorus treatments (Table- 2 & 3). In the current study, onion bulb yield analysis of variance over two years demonstrated that the yield of fresh bulb yield in each study year responded significantly ($P<0.05$) to the graded P levels. Overall, in the pooled study, the average two-year yield increased with a rise in phosphorus levels and the highest significant fresh bulb yield (18.58 t ha^{-1}) recorded in T4 (60:200:60 Kg ha^{-1}), and was shown to be statistically equal to the yield (18.41 t ha^{-1}) from T3 (60-160-60 Kg ha^{-1}). The average onion yield in the first and second years was 20.42 t ha^{-1} and 17.66 t ha^{-1} respectively, and was also recorded in T4 (60:200:60 Kg ha^{-1}). Both these maximum yields were also statistically equal to the yield (20.19 t ha^{-1}) and (17.52 t ha^{-1}) obtained from NPK @ 60-160-60 Kg ha^{-1} in T3 during the first and second years. Subsequently, in a pooled two-year analysis (Table 3), T4 NPK (60:200:60 Kg ha^{-1}) yielded 18.58 t ha^{-1} and T3 NPK (60:160:60 Kg ha^{-1}) yielded 18.41 t ha^{-1} and were found to be significant compared to T2 NPK (60:120:60 Kg ha^{-1}) yielding 16.99 t ha^{-1} and T1 NPK (60:80:60 Kg ha^{-1}) yielding minimal fresh bulb yield (12.82 t ha^{-1}).

Table-2: Response of onions to graded NPK fertilizer doses (Study in 1st year).

Nutrients (Kg ha^{-1})				Yield onion bulb (t ha^{-1})
Tr. No.	N	P_2O_5	K_2O	(First Year)
				Pooled annual average 1(3R)*
1	60	80	60	13.68c
2	60	120	60	18.83b
3	60	160	60	20.19a
4	60	200	60	20.42a
	LSD (0.05)			0.51

*No. of experiments (replications)

Table-3: Response of onions to graded NPK fertilizer doses (Study in 2nd year) and pooled results.

Nutrients (Kg ha^{-1})				Yield onion bulb (t ha^{-1})			
Tr. No.	N	P_2O_5	K_2O	1(3R)*	1(3R)*	Pooled annual average 2(6R)*	Pooled average of two years 3(9R)*
1	60	80	60	13.27c	11.52c	12.39c	12.82c
2	60	120	60	18.72b	13.44b	16.08b	16.99b
3	60	160	60	19.94a	15.09a	17.52a	18.41a
4	60	200	60	20.11a	15.21a	17.66a	18.58a
	LSD 0.05			0.49	0.36	1.13	0.79

*No. of experiments (replications)

c. ***Partial review of the budget:*** As part of the economic study, a partial budget was generated to evaluate the overall cost variability and the gross margin for each fertilizer treatment of the pooled data of three experiments with nine replications. The highest gross return (Rs. 687460.00 ha^{-1}) and gross margin (Rs. 652300.00 ha^{-1}) was obtained from the treatment receiving NPK (60:200:60 Kg ha^{-1}) in T4 (Table 4). The lowest gross return (Rs. 474340.00 ha^{-1}) and gross margin (Rs. 453940.00 ha^{-1}) was obtained from T1 treatment, indicating that output dropped sharply with reduced use of P fertilizer and minimized benefit.

Table-4: Economic analysis and marginal rate of return for onion production as influenced by different fertilizer doses.

Nutrients (Kg ha^{-1})				. Economic analysis and marginal rate of return (t ha^{-1})							
Tr. No.	N	P_2O_5	K_2O	Fertilizer cost (Rs ha^{-1})	Onion bub yield (t ha^{-1})	Increase over T1 (t ha^{-1})	Increase over T1 (percentage)	Gradual increase (percentage)	Gross turn around (Rs ha^{-1})	Benefit cost ratio (BCR)	Gross Margin= (Gross turnaround-Cost of nutrients) (Rs ha^{-1})
1	60	80	60	20400	12.820	0	0		474340	23.25	453940
2	60	120	60	25320	16.990	4.17	33	33	628630	24.83	603310
3	60	160	60	30240	18.410	5.59	44	8.36	681170	22.53	650930
4	60	200	60	35160	18.580	5.76	45	1.0	687460	19.55	652300

† Nutrient price (Price Kg^{-1}): N= Rs 76, P_2O_5= Rs 123, and K_2O= Rs 100; Average farm price of onion Kg^{-1}: Rs 37

DISCUSSION

The increase in the maximum bulb yield could be explained by a higher marketable bulb weight per plant which could be due to the use of balanced fertilizers. In addition, the use of chemical fertilizers may have helped to maintain soil fertility and provided a hostile response to the required nutrient uptake by plants, expounding higher yields. The reduced dose of P fertilizer in T1 and T_2 did not display higher yields of onion. High P-response amounts have been observed and the maximum yield has been increased up to 5.76 t ha^{-1} over T1. The graded dose of P @ 120, 160 and 200 Kg ha^{-1} lifted fresh bulb onion by 33%, 44% and 45% over T1 respectively. Marketable yield ranged from 12.82 to 18.58 t ha^{-1} attributable to P graded doses, the latter estimated at 200 Kg P ha^{-1}. Increasing the phosphorus rate from 80 to 200 Kg P ha^{-1} substantially increased marketable yield of fresh bulbs by 45 per cent. Increasing the phosphorus rate from 80 to 120 Kg P ha^{-1} increased the marketable fresh bulb production by 33 per cent, increased the rate from 120 to 160 Kg P ha^{-1} increased the marketable fresh bulb production by another 8.36 per cent, and increased the rate from 160 to 200 Kg P ha^{-1} increased sellable fresh bulb production by 1.00 per cent (Table 4). This may be due to onions that are highly dependent on arbuscular mycorrhizal fungi (AMF) to take phosphorus from low to medium soil P soils. It can be attributable to onions that are highly dependent on AMF to take phosphorus in some high-pH calcareous soils from low to medium soil (Horneck, 2004). The economic study reveals that treatment arrangements for total fertilizer costs per hectare in descending order appeared as T4 (Rs. 687460.00) T3 (Rs. 681170.00), T2 (Rs. 628630.00), and T1 (Rs. 474340.00). The economic research shows that treatments for gross margin per hectare in decreasing order appeared as T4 (Rs. 652300.00), T3 (Rs. 650930.00), T_2 (Rs. 603310.00), and T1 (Rs. 453940.00). Compared to T3 treatment, farmers should not choose treatment T1 and T2 and even T4 as treatments had lower gross margin or high cost for T4. Nutshell of the entire economic review is that the best economically appropriate choice is to apply NPK @ 60-160-60 for growing onion.

Conclusions: To assess onion fertilizer requirements, three experiments were carried out at farmers' fields with a total of nine replications in Randomized Complete Block Design (RCBD). Two years of consecutive research on farmers' fields revealed that the maximum (18.58 t ha^{-1}) marketable fresh onion bulb yield was obtained from the NPK fertilizer combination @ 60-200-60 Kg ha^{-1} (T_4) treatment and was shown to be statistically equal to the yield (18.41 t ha^{-1}) from NPK @ 60-160-60 Kg ha^{-1} in T3. But the nutshell of the overall economic analysis is that farmers' best economically reasonable option is to apply NPK @ 60-160-60 to grow onion.

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