NPK REQUIREMENTS OF TURMERIC FOR CULTIVATION IN PUNJAB

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ABSTRACT: Turmeric (*Curcuma longa* L.) is an important commercial crop grown since ancient times because of its aromatic rhizomes mainly used for medicinal, culinary and cosmetic purposes. Turmeric is cultivated nearly throughout Pakistan and Punjab province is a major contributor to turmeric production. Fertilizer rates are great determinants of the yield of turmeric. Therefore, this study was conducted at this standing point on the nutritional requirements (NPK) to produce high turmeric yield and suggest a solid adequate NPK dose for turmeric production following long-term field experiments including confirmatory studies. Thus, in 2009 to 2011, five experiments were performed on farmers' fields, with treatments consisting of five nitrogen levels (0, 60, 120, 180, and 240 Kg ha^{-1}), four phosphorus rates (0, 40, 80, and 120 Kg ha^{-1}) and three potassium rates (0, 40, and 80 Kg ha^{-1}) repeated three times in Randomized Complete Block Design (RCBD) to assess fertilizer requirement. Based on results obtained from 2009 to 2011, two experiments were performed in 2012 with treatments consisting of one nitrogen rate (180 Kg ha^{-1}), five phosphorus levels (80, 120, 160, 200, and 240 Kg ha^{-1}) and two potassium rates (40 and 80 Kg ha^{-1}) with three replications as a confirmatory study-1 to confirm the NPK requirement. In 2013 to 2016, five studies on farmers ' fields were performed with treatments consisting of one nitrogen rate (180 Kg ha^{-1}), six phosphorus levels (80, 120, 160, 200, 240, and 280 Kg ha^{-1}) and two potassium rates (40 and 80 Kg ha^{-1}) with three replicates as a confirmatory studies 2, 3, 4 & 5 to confirm the NPK requirement. The results showed that by applying NPK @180:280:80 Kg ha^{-1}, the maximum significant fresh turmeric rhizome yield was obtained and can be recommended with trust for the farmers. It is also established that phosphorus requirement of the turmeric crop is much higher than that of N and K particularly on the soil deficient in available phosphorus.

Keywords: Farmers' fields, NPK requirement, Soil fertility, Turmeric yield.

(Received 08.09.2020 Accepted 25.11.2020)

INTRODUCTION

Improved agricultural intensification and land urbanization have resulted in shifts in cropping systems such as turmeric mono culture. A trend in turmeric cultivation has increasing and the crop area is exhibiting a rising trend (Saeed *et al*., 2017). Turmeric (*Curcuma longa* L.) is an important commercial crop grown since ancient times because of its aromatic rhizomes mainly used for medicinal, culinary and cosmetic purposes (Prasad and Aggarwal, 2011). Turmeric holds a prominent position among the spices, and it is believed that turmeric oil has anti-inflammatory and anti-arthritic properties (Ojikpong, 2018). It is widely grown in such countries as India, China, Nigeria, Pakistan, Myanmar, Indonesia, Bangladesh, Sri Lanka, Taiwan, etc. India ranks first in the region and in production among these countries (Dhanalakshmi *et al*., 2018). The key importing countries are Japan, Singapore, Iran, the United Arab Emirates (UAE), Bangladesh, the Netherlands and Sri Lanka, which account for almost 80% of the world's turmeric trade (Ravindran *et al*., 2007). The farmer will boost his economic status by adopting turmeric cultivation (Verma *et al*., 2019). Turmeric demands high mineral nutrients and typically responds to enhanced soil fertility (Karthikeyan, *et al*., 2012; Singh *et al*., 2001). Besides, the crop has a long growing period (up to 9 months), therefore, the nutrient requirement period also becomes prolonged (Ojikpong, 2018) that exhausts the soil fertility rapidly and to maintain soil fertility for viable crop production is inevitable. Nitrogen is often the element most restricting to crop production. Several studies indicated that the application of nitrogen had a significant effect on growth and yield of turmeric (Agere and Shiferaw, 2015; Hikaru, *et al*. 2007; Shashidhar and Sulikeri, 1996). It has also been documented that nitrogen application not only increases the turmeric yield but also improves the quality attributes (Hikaru *et al*., 2007). Application of nitrogen also improves the fertilizer use efficiency of P and K fertilizers to improve turmeric yield (Pandey, 1992). Total fresh yield reported with the use of NPK @120:60:60 Kg ha^{-1} (Adekiya *et al*., 2018, Ahmed

and Muthuswamy, 1981; Balashanmugam and Chezhiyan, 1986; Umate *et al*., 1984). The effect of nutrient management on arrowroot yields was studied by Suja *et al*. (2006) and it was found that application of N, P, and K @ 50:25:75 Kg ha^{-1} was optimal for better yield (23.29 t ha^{-1}). Though, with application of NPK @120:60:120 Kg ha^{-1}, Verma *et al*. (2019) recorded the highest yield of fresh rhizome (28.17 t ha^{-1}) and found superior in turmeric plant growth, yield, and economy. Hence, the lack of fertilizer requirement for turmeric is one of the main barriers faced in Pakistan by turmeric growers. In Pakistan, turmeric is considered a minor crop, which is why little empirical work on turmeric crops was undertaken for its cultivation and production (Saeed *et al*., 2017). Therefore, this study was conducted at this standing point on the nutritional requirement (NPK) to produce high turmeric yield and suggest a solid adequate NPK dose for turmeric production following long-term field experiments including confirmatory studies in Kasur district of Punjab, Pakistan.

MATERIAL AND METHODS

Five field experiments were performed in 2009 to 2011, one in 2009, two in 2010 and two in 2011 on separate farmers' fields in Kasur district of Punjab, Pakistan, repeated three times in Randomized Complete Block Design (RCBD) to assess NPK fertilizer levels under the supervision of Soil Fertility Research Institute's field staff, Punjab. Ten treatments of five levels of nitrogen (0, 60, 120, 180, and 240 Kg ha^{-1}), four rates of phosphorus (0, 40, 80, and 120 Kg ha^{-1}) and three rates of potassium (0, 40, and 80 Kg ha^{-1}) were applied in central rotatory design. Based on the results obtained from 2009 to 2011, two experiments on farmers' fields were performed in 2012 with treatments consisting of one nitrogen rate (180 Kg ha^{-1}), five phosphorus levels (80, 120, 160, 200, and 240 Kg ha^{-1}) and two potassium rates (40 and 80 Kg ha^{-1}) with three replications as a confirmatory study-1 to confirm the NPK requirements. Five studies on farmers' fields were performed in 2013 to 2016, one in 2013, one in 2014, one in 2015 and two in 2016, with inclusion of one more level of phosphorus @ 280 Kg ha^{-1} with three replicates as a confirmatory study 2, 3, 4 and 5, respectively to confirm the NPK requirements. At the time of sowing, fertilizers, all phosphorus (as diammonium phosphate, DAP), all potassium (as potassium sulphate, SOP), and one-fourth nitrogen (as urea) were used. Remaining three fourth nitrogen (as urea) was added on 30, 60, and 90 days after planting, in three equal parts. Each treatment plot size was 1/40 of hectare. The province of Punjab is a major contributor to turmeric production, where Kasur district has a 72% share of total output in 2013 and town Changa Manga in Kasur district is Pakistan's principal marketing center (Saeed *et al*., 2017). According to another source, the major share comes from the district of Kasur which accounts for more than 80% of the country's output (Anwar *et al*., 2012) with 30569 metric tons annual production from 3157 ha. Prior to planting turmeric, the experimental fields were prepared following the farmers' traditional tillage practices. For the current study Roma turmeric variety was chosen. Field plans were designed according to the design specifications, and each treatment was randomly assigned to experimental plots within a block. Surface soil samples (0-15 cm) were collected randomly from each experimental site with the use of auger, and a respective composite sample was prepared before planting. The soil samples were air-dried and sieved with 0.02 mm sieve wire mesh and analyzed for EC, pH, organic matter (Walkley and Black, 1954), available P (Olsen and Sommers, 1982) and exchangeable K (Brown and Warncke, 1988). All tube well water and canal water were used to irrigate the crops. Harvesting was done when the leaves were yellow at maturity, and immediately fresh rhizome yield was collected from randomly selected plot (3 X 3 m^2)/treatment. Detail of the initial soil characteristics is given in Table1 before experimentation.

Table-1: Pre-Sowing Soil Analysis.

Year/ No. of experiments (Replications)	Soil Characteristics									
	EC (dS m^{-1})		pH		OM%		Available P (ppm)		Exchangeable K (ppm)	
	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
2009/ 1(3R)	2.1	-	8.2	-	0.81	-	8.4	-	107	
2010/ 2(6R)	1.95	1.70-2.20	8.2	8.0-8.3	0.63	0.46-0.79	6.9	4.6-9.2	98	86-110
2011/ 2(6R)	1.90	1.70-2.10	7.8	7.6-7.9	0.45	0.44-0.46	4.3	3.9-4.6	88	86-89
2012/ 2(6R)	2.05	1.90-2.20	7.7	7.5-7.8	0.71	0.67-0.75	6.6	6.2-6.9	100	93-107

2013/ 1(3R)	1.3	-	7.6	-	1.00	-	5.4	-	100	-
2014/ 1(3R)	2.40	-	8.0	-	1.10	-	4.8	-	202	-
2015/ 1(3R)	1.6	-	7.8	-	0.87	-	4.0	-	118	-
2016/ 2(6R)	2.10	1.70-2.50	8.1	8.0-8.2	0.83	0.72-0.94	4.9	4.7-5.0	157	115-198

RESULTS

a. **Initial soil fertility analysis of the soil for the experimental sites:** Table 1 displays the initial chemical properties and soil fertility status of the sites used prior to experimentation in district Kasur, Punjab, Pakistan. Soils / sites used for testing in the years 2009, 2010, 2011, 2012, 2013, and 2015. The soils are normal as for salinity & pH concerned, low to medium in organic matter & phosphorous and medium to adequate in potassium.

b. **Fresh turmeric rhizomes yield in the years 2009 to 2011 :** The yield per hectare of fresh turmeric rhizomes is shown in Table 2. In the current study, fresh rhizome yield analysis of variance in 2009, 2010, and 2011 demonstrated that the yield of fresh turmeric rhizome in each study year responded significantly ($P<0.05$) to the graded NPK levels. Overall, the average yield level of three years increased with an increase in fertilizer level and the highest significant fresh rhizome yield (30.18 t / ha) was reported from NPK (180:120:40 Kg ha^{-1}) in T8 followed by NPK (180:80:80 Kg ha^{-1}) in T10 (26.19 t / ha) and found to be significantly equal to T8. Treatment T1 (0:80:40) resulted in a minimum fresh yield of the turmeric rhizomes (14.02 t / ha). T6, T7, T2, T9, T3, T5, and T4 resulted in 16.37 t / ha, 18.50 t / ha, 19.63 t / ha, 20.0 t / ha, 23.35 t / ha, 24.41 t / ha, and 26.77 t / ha respectively if the treatments were structured in ascending order. Major quantum of response was observed for P application followed by N and K.

Table-2: Average yield of fresh turmeric rhizomes (t / ha) in 2009, 2010 and 2011.

Nutrients (Kg / ha)				Average yield of fresh rhizomes (t / ha)			
				Variety=Roma			
Tr. No.	N	P_2O_5	K_2O	2009 1(3R)*	2010 2(6R)*	2011 2(6R)*	Average 5(15R)*
1	**0**	**80**	**40**	15.02f	13.53f	14.02g	**14.02f**
2	**60**	**80**	**40**	22.33de	20.89d	17.03ef	**19.63d**
3	**120**	**80**	**40**	26.31cd	25.73c	19.48cd	**23.35c**
4	**180**	**80**	**40**	31.47ab	29.43b	21.77b	**26.77b**
5	**240**	**80**	**40**	27.53bc	26.87c	20.38bc	**24.41c**
6	**180**	**0**	**40**	21.16e	14.55f	15.80f	**16.37e**
7	**180**	**40**	**40**	23.35de	16.56e	18.03de	**18.50d**
8	**180**	**120**	**40**	34.60a	33.38a	24.78a	**30.18a**
9	**180**	**80**	**0**	24.62de	20.17d	17.54e	**20.01d**
10	**180**	**80**	**80**	29.82ab	32.68a	24.74a	**28.93a**
			LSD.05	**4.83**	**1.70**	**1.63**	**1.85**

*No. of experiments (replications)

c. Fresh turmeric rhizomes yield in the year 2012 (confirmatory study-1): Table 3 presents the findings of fresh turmeric rhizomes yield / ha for the year 2012. In this confirmatory study-1, a variance analysis of fresh rhizome yield demonstrated that the yield of fresh turmeric rhizome responded significantly ($P<0.05$) to the graded P levels. In general, the average yield increased with P level increase and the highest significant fresh rhizome yield (26.07 t / ha) was reported with P level @ 240 Kg ha^{-1} along with NK (180:80 Kg ha^{-1}) in T5 followed by NPK (180:200:80 Kg ha^{-1}) in T4 (24.02 t / ha) and found to be significantly low as compared to T5. Treatment T1 (180:80:40) resulted in a significant minimum fresh yield of the turmeric rhizomes (16.65 t / ha). Statistically T2 (180: 120: 80) and T3 (180: 160: 80) appeared at par and resulted in 20.75 t / ha and 21.79 t / ha, respectively.

d. Fresh turmeric rhizomes yield in the year 2013 (confirmatory study-2): Table-4 presents the results of the fresh turmeric rhizomes yield / ha for the year 2013. In this confirmatory study-2, a variance analysis of fresh

rhizome yield showed that the yield of fresh turmeric rhizome responded significantly (P<0.05) to the graded P doses. In general, the average yield level increased with P level increase and the highest fresh rhizome yield (38.04 t / ha) was recorded with P level @ 280 Kg ha^{-1} along with NK (180:80 Kg ha^{-1}) in T6 followed by NPK (180:240:80 Kg ha^{-1}) in T5 (35.63 t / ha) and NPK (180:200:80 Kg ha^{-1}) in T4 (35.505 t / ha) and found significantly at par as compared with T6. Treatment T1 (180:80:40) resulted in a minimum fresh yield (32.76 t / ha) of turmeric rhizomes, T2 (180:120:80) and T3 (180:160:80) resulting in 33.34 t / ha and 34.70 t / ha respectively.

Table-3: Percent increase in average yield of fresh rhizomes (2009, 2010 and 2011) over control.

N (Kg / ha)	Average yield of fresh rhizomes (tha^{-1})	% increase over control yield	P_2O_5 (Kg / ha)	% increase over control yield	Average yield of fresh rhizomes (tha^{-1})	K_2O (Kg / ha)	Average yield of fresh rhizomes (tha^{-1})	% increase over control yield
0	14.02	-	0	16.37	-	0	20.01	-
60	19.63	28.58	40	18.50	11.51	40	28.93	30.83
120	23.35	39.96	80	26.77	38.85	80	26.77	25.25
180	26.77	47.6	120	30.18	45.76	-	-	-
240	24.41	42.56	-	-	-	-	-	-

*No. of experiments (replications)

e. Fresh turmeric rhizomes yield in the year 2014 (confirmatory study-3): The results of the year 2014 yield / ha of fresh turmeric rhizomes are also provided in table 4. In this confirmatory study-3, a variance analysis of fresh rhizome yield demonstrated that the yield of fresh turmeric rhizome reacted significantly (P<0.05) to the graded P levels. The average yield increased with P-level increase and the highest fresh rhizome yield (30,03 t / ha) was observed with P-level @ 280 Kg ha^{-1} along with NK (180:80 Kg ha^{-1}) in T6 followed by NPK (180:240:80 Kg ha^{-1}) in T5 (28,78 t / ha) and NPK (180:200:80 Kg ha^{-1}) in T4 (26,63 t / ha) and found significantly lower compared with T6. Treatment T1 (180:80:40) also showed significant minimum fresh yield (22.37 t / ha) of turmeric rhizomes, T2 (180:120:80) and T3 (180:160:80) showed statistically different outcomes, resulting in 24.76 t / ha and 26.03 t / ha respectively.

f. Fresh turmeric rhizomes yield in the year 2015 (confirmatory study-4): Table-5 also presents results of fresh turmeric rhizomes yield / ha in the year 2015. In this confirmatory study-4, a variance analysis of fresh rhizome yield revealed that the yield of fresh turmeric rhizome responded significantly (P<0.05) to the graded P doses. The average yield increased with P-level increases and the highest fresh rhizome yield (32.31 t / ha) was reported with P-level @ 280 Kg ha^{-1} along with NK (180:80 Kg ha^{-1}) in T6 followed by NPK (180:240:80 Kg ha^{-1}) in T5 (30.69 t / ha) and was found to be statistically equivalent to T6. Yield was statistically equivalent in T3, T4, and T5. Treatment T1 (180:80:40) resulted in a minimum fresh yield (26.98 t / ha) of turmeric rhizomes, and was statistically comparable to T2 (180:120:80) at 27.74 t / ha.

Table-4: Average yield of fresh rhizomes (t / ha) in 2012 as Confirmatory Study-1

Nutrients (Kg / ha)				Average yield of fresh rhizomes (t / ha) 2012			
				Confirmatory Study-1			
				Variety= Roma			
Tr. No.	N	P_2O_5	K_2O	1(3R)*	1(3R)*	Average Yield 2(6R)*	% increase in yield over control (T1)
1	180	80	40	19.14d	14.15d	16.65d	
2	180	120	80	23.92c	17.58c	20.75c	19.76
3	180	160	80	24.48bc	19.10bc	21.79c	23.59
4	180	200	80	26.65b	21.40ab	24.02b	30.68
5	180	240	80	28.89a	23.24a	26.07a	36.13
			LSD.05	**2.19**	**2.88**	**1.50**	

* No. of experiments (replications)

g. Fresh turmeric rhizomes yield in the year 2016 (confirmatory study-5): The results of the year 2016 yield / ha of fresh turmeric rhizomes are also provided in Table 5. In this confirmatory study-5, variance analysis of fresh rhizome yield indicated that the yield of fresh turmeric rhizome responded significantly ($P<0.05$) to the level of P graded doses. The average yield increased with P level increases and the highest fresh rhizome yield (37.95 t / ha) was reported with P level @ 280 Kg ha^{-1} along with NK (180:80 Kg ha^{-1}) in T6 followed by NPK (180:240:80 Kg ha^{-1}) in T5 (35.94 t / ha), NPK (180:200:80 Kg ha^{-1}) in T4 (34.77 t / ha), NPK (180:160:80 Kg ha^{-1}) in T3 (32.67 t / ha), NPK (180:120:80 Kg ha^{-1}) in T2 (29.99 t / ha) and NPK (180:80:80 Kg ha^{-1}) in T1 (24.57 t / ha and found significantly different from T6.

Table-5: Average yield of fresh rhizomes (t / ha) in 2013 and 2014 as confirmatory study-2 and 3

Nutrients (Kg / ha)				Average yield of fresh rhizomes (t / ha)	
				Variety=Roma	
Tr. No.	N	P_2O_5	K_2O	2013 1(3R)*	2014 1(3R)*
				Confirmatory Study -2	Confirmatory Study 3
1	180	80	40	32.76b	22.37f
2	180	120	80	33.34b	24.76e
3	180	160	80	34.70b	26.03d
4	180	200	80	35.50ab	26.63cd
5	180	240	80	35.63ab	28.78b
6	180	280	80	38.04a	30.03a
			LSD.05 3.05	1.238	

*No. of experiments (replications).

DISCUSSION

a. Initial soil fertility analysis of the soil for the experimental sites: The soils were non-saline, alkaline in nature, low in organic matter (OM) status, available P, and exchangeable K. While the soils / sites used for experiments in 2014 and 2016 were non-saline, alkaline in nature, low in organic matter (OM) level, available P, but adequate in exchangeable K.

b. Fresh turmeric rhizomes yield in the years 2009 to 2011: Turmeric is a highly nutrient-intensive crop, in this respect *(*Rao *et al*., 1975), with a combination of 375,175, and 237.5 Kg N, P_2O_5, and K_2O, respectively, obtained higher yields of turmeric rhizomes. The increased production of turmeric rhizomes resulting from the application of graded doses of NPK fertilizer was due to the lack of essential nutrients necessary for the growth and yield of turmeric in the soil of the experimental sites (Ogbonna, 2012). Ojikpong (2018) recorded a turmeric response to NPK, too. This response was due to NPK fertilizer, nitrogen promoting leaf growth and involving in protein and chlorophyll formation, while P contributes to root growth, energy transfer reactions, cell division and multiplication and K contributes to the production of stem, cell division, carbohydrate formation and translocation, and primarily the growth of tuber / rhizome in roots. In this study, 60, 120, 180, and 240 Kg N / ha increased turmeric rhizome yield by 28.58 percent, 39.96 percent, 47.6 percent, and 42.56 percent respectively, compared to the control (Table-6). It indicates that N @180 Kg ha^{-1} application provided significantly higher yield compared to N @240 Kg ha^{-1} application. Whereas 40, 80, and 120 Kg P_2O_5 / ha increased rhizome yield over control by 11.51 percent, 38.85 percent, and 45.76 percent respectively, and application of P_2O_5 @120 Kg ha^{-1} yielded the highest significant yield of fresh turmeric rhizome compared to other doses of P_2O_5. The graded dose of K @ 40 and 80 Kg ha^{-1} increased the yield of fresh turmeric rhizome by 30.83 percent and 25.25 percent respectively over control. The significant maximum yield of fresh turmeric rhizome was documented from the maximum rate of P applied (120 Kg P_2O_5 ha^{-1}), suggesting that applying P beyond this level may contribute to crop yield. This was due to the low concentration of soil available P in soils used in the years 2009, 2010, and 2011 prior to experiment. In this three-year analysis, considering the volume of turmeric response in fresh rhizome yield, it appeared that the threshold for high turmeric rhizome yield, P fertilizer was high. In future research, therefore, it was further recommended to add more P levels to produce a definitive result with the maximum turmeric requirement for maximum yield output. Therefore more investigations / confirmatory studies were planned in the coming years based on these findings.

c. Fresh turmeric rhizomes yield in the year 2012 (confirmatory study-1): Major quantum of response was again observed for application of P. When compared with treatment T1, the percentage increase in yield was considered to be a minimum level of NPK @ 180:80:40

(Table-3), 120, 160, 200, and 240 Kg of P_2O_5 ha^{-1} increased turmeric rhizome yield by 19.76%, 23.59%, 30.68%, and 36.13% respectively. It indicates that the application of P @ 240 Kg ha^{-1} provided significantly higher yield compared to other P levels. The significant maximum yield of fresh turmeric rhizome was reported from the maximum rate of P applied (240 Kg P_2O_5 ha^{-1}), suggesting that applying P beyond this level may contribute to crop yield. In this confirmatory test, once again considering the magnitude of turmeric response in fresh rhizome yield, the P fertilizer threshold for high turmeric rhizome yield appeared to be further high. In future research, therefore, it was further advisable to add a higher P rate to produce a conclusive result with the maximum turmeric P requirement for maximum yield output. Therefore, further investigations / confirmatory studies from 2013 to 2016 were planned on the basis of these results.

d. Fresh turmeric rhizomes yield in the year 2013 (confirmatory study-2): Variable results were obtained during this year and did not yield the conclusive / solid results which did not indicate the turmeric's confirmative maximum P requirement for maximum yield output.

e. Fresh turmeric rhizomes yield in the year 2014 (confirmatory study-3): Conclusive results were obtained during this year and the confirmatory maximum P requirement (280 Kg P_2O_5 ha^{-1}) for maximum turmeric yield production was indicated along with NK @ 180:80 Kg ha^{-1}.

f. Fresh turmeric rhizomes yield in the year 2015 (confirmatory study-4): Definitive results were obtained during this year and the confirmatory maximum P requirement (280 Kg P_2O_5 ha^{-1}) for maximum turmeric yield output together with NK @ 180:80 Kg ha^{-1} was indicated.

Table-6: Average yield of fresh rhizomes (t / ha) in 2015 and 2016 as confirmatory study 4 and 5.

Nutrients (Kg / ha)				Average yield of fresh rhizomes (t / ha)	
				Variety=Roma	
Tr. No.	N	P_2O_5	K_2O	2015 1(3R)* Confirmatory Study -4	2016 2(6R)* Confirmatory Study -5
1	180	80	40	26.98c	24.57 e
2	180	120	80	27.74c	29.99 d
3	180	160	80	29.40b	32.67 c
4	180	200	80	29.95b	34.77 b
5	180	240	80	30.69b	35.94 b
6	180	280	80	32.31a	37.95 a
			LSD.05	1.432	1.964

*No. of experiments (replications)

g. Fresh turmeric rhizomes yield in the year 2016 (confirmatory study-5)

Conclusive and confirmed results were obtained during this year, indicating the confirmatory maximum P requirement (280 Kg P_2O_5 ha^{-1}) for maximum turmeric yield production in Kasur district of Punjab, Pakistan, together with NK @ 180:80 Kg ha^{-1}.

Conclusion: The experiments were carried out in a complete randomized block design (RCBD) with three replications on the farmers' fields in Kasur district, Punjab, Pakistan. From the results of twelve replicated experiments with graded doses of NPK conducted on farmers' fields between 2009 and 2016, it can be concluded that the fertilizer levels significantly affected the yield of fresh turmeric rhizomes. This response was due to the lack of essential nutrients, particularly phosphorus responsible for growth and turmeric yield, in the soil of the experimental sites. The results showed that the maximum significant fresh turmeric rhizome yield was obtained from the application of NPK @180:280:80 Kg ha^{-1}. The application of NPK @180:280:80 Kg ha^{-1} can therefore ensure maximum rhizome yield and can be suggested / recommended with trust for the farmers.

Acknowledgements: The authors are grateful to Hafiz Hussnain Barkat Qazi, Sidra Qazi, and Marfowa Qazi for their assistance especially in writing the manuscript.

REFERENCES

Adekiya, A.O., E.T. Alori, C.M. Aboyeji, O. Dunsin, K.A. Adegbite, C.O. Aremu, O. Bamiro, W.S. Ejue, F.O. Okunlola and O.O. Adesola (2019). MgO fertilizer sole and combined with organic and inorganic fertilizers: effect on soil chemical properties, turmeric performance, and quality in a tropical Alfisol. Sci. World J. https://doi.org/10.1155/2019/8140276

Agere, L. and T. Shiferaw (2015). Determination of optimum rate of nitrogen and phosphorous fertilizers for the yield and yield components of turmeric (Curcuma longa L.) on Nitisols at YakiWoreda Southwestern. J. Agr. Sci. 3(10): 289-295.

Ahmed, S. and S. Muthuswamy (1981). Studies on the influence of nitrogen on the yield and yield components of turmeric (*Curcuma longa* L.). Indian Cocoa, Arecanut & Spices J. 5: 9-10.

Balashanmugam, P.V. and N. Chezhiyan (1986). Effect of differential application of nitrogen on growth and yield of turmeric (Curcuma longa L.). Madras Agric. J. 73(8): 439-442.

Brown, J.R. and D.D. Warencke (1988). Recommended cation tests and measures of cation exchange capacity in Dahnke, W.C. (ed.): Recommended chemical soil test procedures for North Central Region. Bull. No. 499, 15–16 North Dakota Agric. Exp. Stn., Fargo, ND.

Dhanalakshmi, K., K. Chitra, R. Manimekalai, C.Balisasikumar and K.K.Vijayakumari (2018). Production and Economics of Turmeric Cultivation. Int J CurrMicrobiol App Sci. 7(11): 3496-3502.

Hikaru, A., H. Amzad, I. Yukio and Y. Kenichi, H. Kazuo (2007). Effects of application of N, P and K alone application of N, P and K alone or in combination on growth, yield and curcumin content of turmeric (Curcuma longa L.). Plant Prod Sci. 10(1): 151-154.

Karthikeyan, P., M. Ravichandran, P. Imas, M. Assaraf (2012). Application of potassium and magnesium on turmeric (Curcuma longa) to increase productivity in Inceptisols, Arch. Agron. Soil Sci. 58, 10.1080/03650340.2012.695866.

Ogbonna, P.E. and N.J. Nweze (2012). Evaluation of growth and yield responses of cocoyam (Colocasiaesculenta) cultivars to rates of NPK15:15:15 fertilizer. Afr. J. Agric. Res. 7(49): 6553–6561.

Ojikpong, T.O. (2018). Effect of Planting Dates and NPK (15:15:15) Fertilizer on the Growth and Yield of Turmeric (Curcumalonga Linn).SSRG – IJAES. 5(4):42-46.

Olsen, S.R. and L.E. Sommers (1982). Phosphorus, in Page, A.L.(ed.): Methods of Soil Analysis Part 2 Chemical and Microbiological Properties, American Society of Agronomy, Soil Science Society of America, Madison, pp. 403-430.

Pandey, A. (1992). Response of turmeric to various levels of nitrogen under terrace conditions of mid altitude. Mizoram. Indi Coc Are Spi J. 16(1): 14-16.

Prasad, S. and B.B. Aggarwal (2011). Turmeric, the Golden Spice. Herbal medicine: biomolecular and clinical aspects, in Packer L. (ed.): Ong CN. New York: CRC Press, pp. 263-288.

Verma, S., P. Pratap, R.C. Padalia, V.R. Singh, A. Kumar and B.K. Agri (2019). Effect of nitrogen, phosphorus and potassium levels on growth and yield of turmeric (Curcuma longa L.) Under the Katyur valley of western Himalayan region of Uttarakhand. J. Med. Plants Stud. 7(2): 117-122.

Rao, M.R., K.R.C. Reddy and M. Subbarayudu (1975). Promising turmeric types of Andhra Pradesh. Indian Spices. 12: 2–5.

Ravindran, P., K. Ravindran, B.Nirmal and K.Sivaraman (2007). Turmeric: the genus Curcuma; Medicinal and aromatic plants-industrial profiles, pp. 234-236.

Saeed, R., A. Bashir, S.B. Khan, K. Bakhsh and M. Qasim (2017). An economic assessment of turmeric production in Punjab-Pakistan. Pak. J. Agri., Agril. Engg. Vet. Sci. 33 (1): 85-99.

Shashidharand, T. and G. Sulikeri (1996). Effect of plant density and N levels on growth and yield of turmeric (Curcuma Longa L.). Division of Horticulture, University of Agricultural Sciences, Dharwad. Karnat. J Agri sci. 9 (3): 483-488.

Singh, P., R. Srivastava, A. Sharma, D. Hore and B. Panwar (2001). Genetic variability and correlation in turmeric (Curcuma longa L.). Indian J. Hill Farming. 14: 24-28.

Suja, G., T.V.R. Nayar and C.S. Ravindran (2006). Influence of nutrient management in arrowroot (Marantaarundinacea L.) on biomass production, nutrient uptake and soil nutrient status. J. Root Crops. 32: 162-165.

Umate, M.G., A. Latchanna and U.S. Bidgire (1984). Growth and yield of turmeric varieties as influenced by varying levels of nitrogen. Indi Coc Are Spi J. 8: 23- 57.

Walkley, A. and C.A. Black (1934). An estimation of methods for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37: 29-38.