Optimizing phosphorous dose for higher paddy yield under agro-ecological conditions of Sheikhupura

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ABSTRACT

Phosphorus fertilization for getting higher paddy yields is quite necessary owing to its vital role in crop plant development, so a field experiment was conducted to evaluate the appropriate level of phosphorous fertilizer for rice (Super basmati) at Adaptive Research Farm, Sheikhupura during Kharif 2012, 2013 and 2014. Different levels of phosphorous (34, 45, 68, 90, 102 and 136 kg ha^{-1}) were used as treatments in randomized complete block design (RCBD) with 3 replications. The crop was sown using traditional transplanting method during 1st week of July every year. All other agronomic practices were kept uniform for the entire growth season every year. Data related to agronomic parameters including plant height, number of productive tillers, number of grains per spike, 1000-grain weight and paddy yield was recorded using standard procedures. Results revealed that 90 kg ha^{-1} phosphorous was the most appropriate dose for getting maximum paddy yield under agro-ecological conditions of Sheikhupura.

Key words: phosphorous, paddy, rice, fertilizer

Pakistan has 4th position among rice producing countries of the world after China, India and Indonesia. In addition to domestic use of rice grain, rice is also exported by Pakistan making it 2nd most important source of foreign exchange. Rice is grown on about 10% of total cultivated area of Pakistan. In Pakistan, actual yield of rice crop is far less than the potential yield that can be attributed to many factors including: low plant population, soils poor in organic matter, low fertilizer use efficiency, poor management of insects-pests and post harvest losses due to poor management.

Fertilizers have prime importance in today's agriculture as they provide necessary nutrients to the crops. Application of fertilizer unwisely can lead to negative consequences and desirable results may not be achieved. Integrated nutrient management is the approach in which fertilizers are applied in such a way that it may enhance the crop productivity without compromising environment as well as crop health (Ernst & Mutert, 1995). Among different types of essential nutrients supplied to the crop plants through fertilization, phosphorous has key position. It is involved in many vital functions of the plant as well as an integral part of many cellular compounds like DNA, ATP and RNA (Khan et al., 2010). It is a mobile element in plant and its deficiency symptoms can be seen on young tissues of plant. Phosphorous deficiency at earlier crop growth stages results in stunted growth while poor seed development and delayed crop maturity are the signs for deficiency at later stages.

Generally soils contain 100 to 2000 mg kg $^{-1}$ phosphorous and the top 25 cm layer of soil has about 300-7000 kg ha^{-1} of phosphorous but the major problem of phosphorous is its fixation (Sharif et al., 2000). Alkaline and calcareous soils have the ability to adsorb P very rapidly and this adsorbed P is not available for the plant roots (Huang, 1998). A survey conducted by Malik et al (1984) showed that Pakistani soils are calcareous in nature with very low available P (5-10%) which is very low level of phosphorous.

Phosphorous in frequently used in rice crop across the world for getting higher crop yields, however phosphorous use efficiency of rice is very low (10-20%). It is also documented that for harvest of one tone of rice, 15-20 kg nitrogen, 2-3 kg phosphorous and 15-20 kg potassium is required that should be compensated to soil through fertilization. It indicates that much of the applied phosphorous is unavailable for the crop plant (Shin et al, 2004). Moreover, fixing of phosphorous by soil is also a reason for low phosphorous use efficiency. So Phosphate fertilizers if used at same pace for crop production, soon the rock phosphate, natural reservoir of phosphorous will exhaust from the world. Higher prices of phosphorous fertilizers are also a major issue that demands its exact quantification for actual crop requirements so that it must be used wisely to get maximum returns in long run (Twyford, 1994). A field experiment was performed at Adaptive Research Farm, Sheikhupura for studying the optimum phosphorous requirements of the rice crop.

MATERIALS AND METHODS

Site description

The proposed study was performed at Adaptive Research Farm, Sheikhupura for 3 consecutive years: 2012, 2013 and 2014. The experimental site lies between latitude $31^o - 42^o$ N and longitude $73^o - 59^o$ E on the globe at an altitude of 209.57 m in rice-wheat cropping system of Pakistan. The climate of the site is moist sub-humid and rain fall ranges from 250 to 500 mm annually. Soil analysis was also performed to find the different soil physio-chemical properties and it revealed that the soil was loamy in nature with relative proportion of sand, silt and clay was 14%, 70% and 16%, respectively (Moodie et al., 1959). Chemical analysis showed that the soil has 0.8% organic matter, 10.1% total soluble salts, 8.4 pH, 0.07%, 10.4 ppm and 204 ppm as total nitrogen, available phosphorous and potash, respectively.

Crop husbandry

Each year rice nursery grown in 2nd week of June was transplanted to puddled soil manually at the age of about 30 days. Full dose of potash (62 kg ha^{-1}) and 1/3 of recommended dose of nitrogen (136 kg ha^{-1}) was applied at the time of puddling, while the remaining nitrogen was applied in 2 equal doses at 20-25 and 50-55 days after transplanting the nursery. Source of nitrogen was urea and of potash was sulphate of potash (SOP). Moreover, zinc was also applied @ 5 kg ha^{-1} in the form of zinc sulphate (33%) at active tillering stage. Other agronomic practices from sowing to harvesting were kept uniform for all experimental units for all three years of experimentation. Each year, crop at maturity was harvested manually and threshed to measure different agronomic parameters like plant height, productive tillers, grains per spike, grain weight index and paddy yield.

Experimental Design and Treatments

The experiment was laid out in Randomized Complete Block Design (RCBD) and different concentrations of phosphorous (34, 45, 68, 90, 102 and 136 kg P_2O_5) as treatments. Phosphorous was applied in the form of SSP at the time of puddling to all experimental units according to the treatment structure. The net plot size was 3.78 m × 3.12 m for each experimental unit.

Statistical Analysis

The collected data was analyzed statistically by employing the Fisher's analysis of variance technique. The significance of treatment means was tested using least significance difference (LSD) test at 5% probability level (Steel et al., 1997). Moreover, correlation analysis of paddy yield with different concentrations of phosphorous was also performed to find the impact of phosphorous on paddy yield.

RESULTS AND DISCUSSION

Plant height (cm)

Data presented in Table-2 shows that different levels of phosphorous significantly affected the plant height of rice (super basmati) during all three years of study. Maximum plant height (108.3, 103.0 and 104.0 cm for 2012, 2013 and 2014, respectively) was recorded when phosphorous was applied @ 90 kg ha^{-1}. Moreover, during 2013, plant height at 68, 102 and 136 kg ha^{-1} of applied phosphorous was statistically similar to that of phosphorous applied @ 90 kg ha^{-1}. However, minimum plant height (99.0, 98.3 and 99.7 cm for 2012, 2013 and 2014, respectively) was found when phosphorous was applied @ 34 kg ha^{-1}. Plant height of rice increased with the increase in P levels up to a limit of 90 kg ha^{-1} might be due to phosphorus's role in plant growth and development.

Table 1. Effect of different levels of Phosphorous on plant height, number of productive tillers, number of grains per spike, 1000-grain weight and paddy yield of rice (Super Basmati) during Kharif 2012, 2013 and 2014

Phosphorous (kg ha^{-1})	Plant height (cm)			Number of productive tillers (m^2)			Number of grains per spike			1000-grain weight (g)			Grain yield (t ha^{-1})		
	2012	**2013**	**2014**	**2012**	**2013**	**2014**	**2012**	**2013**	**2014**	**2012**	**2013**	**2014**	**2012**	**2013**	**2014**
34	99.0d	98.3b	99.7c	119.0d	122.3c	125.7d	101.0e	101.7c	101.3c	20.5c	20.5c	20.6d	2.66e	2.67e	2.73e
45	102.0c	99.3b	100.3bc	121.0c	124.0bc	127.0cd	102.0de	104.3c	103.7c	20.8b	20.6c	20.9cd	2.72d	2.77d	2.82d
68	104.0b	102.3a	102.3ab	121.7c	125.7ab	130.0ab	104.0bc	109.7ab	110.7ab	21.0ab	21.2b	21.0c	2.92b	2.94c	3.01b
90	108.3a	103.0a	104.0a	127.3a	127.0c	132.0a	106.3a	112.3a	112.7a	21.3a	21.6a	22.1a	3.05a	3.18a	3.24a
102	104.3b	102.3a	103.3a	125.0b	126.7a	131.0a	104.7b	110.3ab	111.3a	21.1ab	21.2b	21.8ab	3.00a	3.05b	3.04b
136	103.3bc	102.0a	103.0a	121.0c	124.3bc	129.0bc	103.0c	107.7b	108.0ab	20.8b	20.8c	21.5b	2.80c	2.86c	2.90c
LSD (0.05)	1.88	2.22	2.52	1.99	2.18	2.69	1.63	2.68	2.89	0.28	0.31	0.42	0.047	0.078	0.049

[*]Means not sharing the same letter within a column differ from each other at $p \leq 0.05$

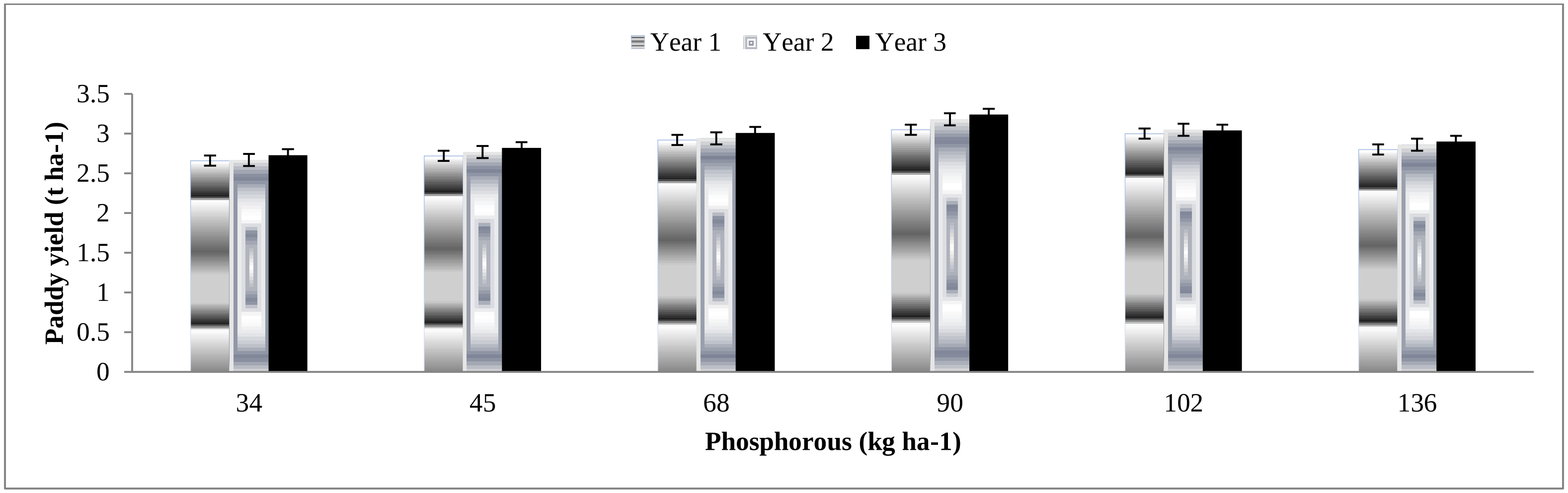

Fig 1. Paddy yield of rice (Super basmati) as affected by different levels of Phosphorous fertilizer during 2012, 2013 and 2014.

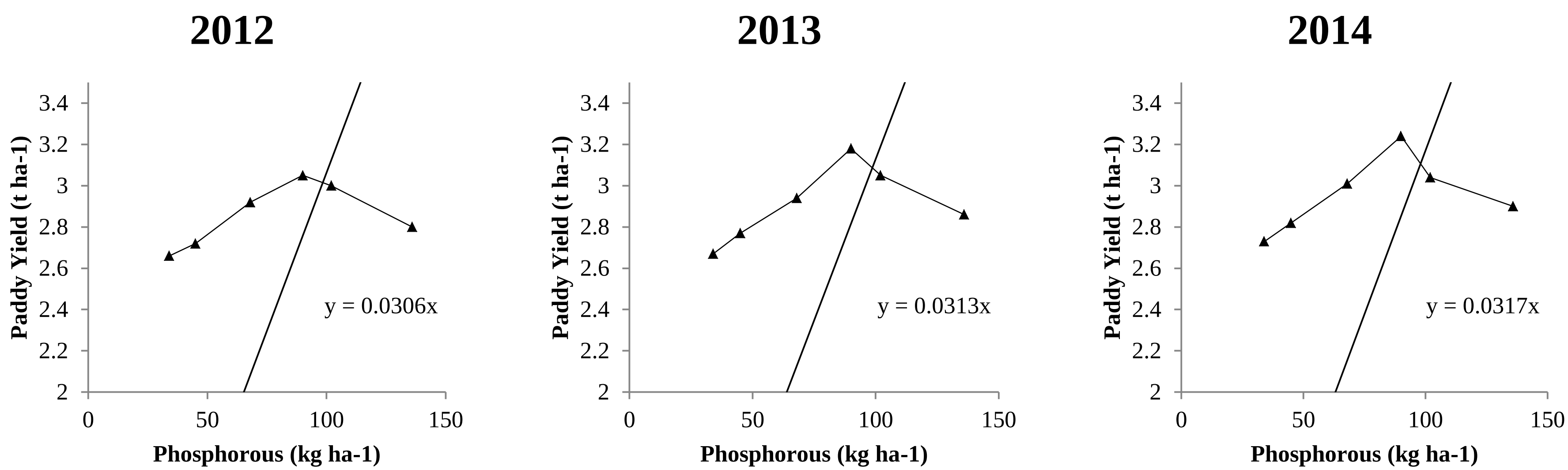

Fig 2: Co-relation analysis of P and yield of rice (super basmati) during Kharif-2012, 2013 and 2014 at Adaptive Research Farm, Sheikhupura

No of productive tillers (m^{-2})

Productive tillers in rice are active factor in determining yield. Different phosphorous levels significantly affected the tillering in rice (super basmati) during 2012, 2013 and 2014 as presented in Table-2. Maximum number of productive tillers (127.3, 127.0 and 132.0 for 2012, 2013 and 2014, respectively) was recorded when phosphorous was applied @ 90 kg ha^{-1}. Moreover, during 2013 and 2014, tillering at 102 kg ha^{-1} of phosphorous was also statistically similar to phosphorous applied @ 90 kg ha^{-1}. Data also showed that tillering increased with increasing phosphorous concentration up to a certain level and then it started diminishing as at P= 136 kg ha^{-1} tillering is lower as compared to the tillering at 102 kg ha^{-1} and 90 kg ha^{-1}. Minimum number of productive tillers (119.0, 122.3 and 125.0 for 2012, 2013 and 2014, respectively) during all three years were recorded when phosphorous was applied @ 34 kg ha^{-1}. Tillering in rice enhanced with the higher doses of phosphorous up to 90 kg ha^{-1} shows that this is the most suitable phosphorous level for rice crop as higher P doses like 102 and 136 kg ha^{-1} could not significantly increase the number of productive tillers m^{-2} in rice super basmati during all three years of experimentation (Table 2). Similar findings were also reported by Matsua et al (1995) that adequate supply of P fertilizer helps rice plant in increasing its tillering capacity.

Number of grains per spike

Number of grains per spike in rice was also significantly affected by different levels of phosphorous. Maximum number of grains per spike (106.3, 112.3 and 112.7 for 2012, 2013 and 2014, respectively) were recorded at 90 kg ha^{-1} phosphorous. A similar trend was observed every year *i.e.* application of phosphorous increased number of grains per spike up to a certain limit and then decrease was observed. Minimum number of grains per spike (101.0, 107.0 and 101.3 for 2012, 2013 and 2014, respectively) was recorded at lowest phosphorous level *i.e.* 34 kg ha^{-1}. Number of grains per spike in rice was highest at 90 kg ha^{-1} phosphorous, but further increment in P supply could not increase the number of grains per spike in rice (Table 2) Moreover, reduced number of grain per spike at lower phosphorous levels may be due to phosphorous deficiency as it is also reported that phosphorous deficiency can decrease number of panicles and number of grains per panicle in rice (Aide and Picker, 1996) while Sahar and Burby (2003) recommended 70 kg ha^{-1} phosphorous as the optimum level of phosphorous for obtaining higher number of grains per spike in rice.

1000-grain weight (g)

Different levels of phosphorous (34, 45, 68, 90, 102 and 136 kg ha^{-1}) significantly affected the 1000-grain weight of rice (super basmati) during all the years of experimentation. Maximum 1000-grain weight (21.3, 21.6 and 22.1 g for 2012, 2013 and 2014, respectively) was recorded with the application of phosphorous @ 90 kg ha^{-1} (Table 1). Moreover, phosphorous levels 102 kg ha^{-1} was statistically at par with phosphorous level 90 kg ha^{-1} during 2012 and 2014 and also during 2012, phosphorous level of 68 kg ha^{-1} was also statistically at par with Phosphorous @ 90 kg ha^{-1}. Minimum 1000-grain weight (20.5, 205 and 20.6 g for 2012, 2013 and 2014, respectively) was recorded with lowest dose of phosphorous *i.e.* 34 kg ha^{-1}. Similar to other parameters, 1000-grain weight also increased up to 90 kg ha^{-1} and started declining (Table 2). 1000-grain weight of rice also showed similar trend during all 3 years of experiment. These results are in line with those Alam et. al., (2009) and Fageria (1991), who found that phosphorous has a significant effect on 1000-grain weight and paddy yield of rice.

Paddy yield (t ha^{-1})

Paddy yield of rice (super basmati) was significantly affected by varying rates of Phosphorous application during all the years of study (Table-2). Maximum paddy yield of super basmati (3.05, 3.18 and 3.24 t ha^{-1} for 2012, 2013 and 2014, respectively) was recorded when phosphorous was applied @ 90 kg ha^{-1}. However, during 2012, paddy yield with Phosphorous applied @ 102 kg ha^{-1} (3.00 t ha^{-1}) was also statistically similar to phosphorous @ 90 kg ha^{-1}. When a yield comparison was done using bar graph for 3 years, it was observed that highest paddy yield was achieved when phosphorous was applied @ 90 kg ha^{-1} (Fig-1) and co-relation analysis for yield as function of Phosphorous also showed that with increase in phosphorous applied to rice, yield also increases up to a level of 90 kg ha^{-1}, but further increments in

Phosphorous dose reduced the yield (Fig 2). Our results are in line with those of Hussain et al 2009; Heenan and Battan, 1986; Fageria, 1999; Mahajan et al., 1994 and Subba Rao et al., 1995 as all of them reported that increasing phosphorous, increases the yield of rice.

CONCLUSION

In conclusion, application of phosphorous @ 90 kg ha^{-1} is the optimum level of phosphorous for obtaining higher paddy yields under agro-ecological conditions of Sheikhupura, Pakistan.

REFERENCES

Aide, M. and J. Picker. 1996. Potassium and Phosphorus Nutrition in Rice. Information from Missouri Rice research Update.

Alam, M.M., H.M. Ali and M. Amin. 2009b. Yield attributes, yield and harvest index of three irrigated rice varieties under different levels of phosphorus. *Advances in Biological Research*, **3 (3-4):** 132-139.

Alam, M.M., M.H. Hasanuzzaman and K. Nahar 2009a. Growth pattern of three high yielding rice varieties under different phosphorus levels. *Advances in Biological Research*., **3(3-4):** 110-116.

Ernst, W. and E. Mutert. 1995. Plant Nutrient Balances in the Asian and Pacific Region – The Consequences for Agricultural Production. In Food and Fertilizer Development Centre 2005. An International Information Centre for farmers in the Asia-Pacific region, Taiwan R. O. C.

Fageria, N.K. 1991. Response of rice cultivars to Phosphorous fertilizer on dark red Latosols in Central Brazil. Revista Brasileria-de-*Ciencia-do-solo.*, **15(1):** 63-67.

Heenan, D.P. and G.D. Batten. 1986. Response to Superphosphate by rice in an annual rice cropping system to Southern New South Wales. *Aust J of Experimental Agric.*, **26(9):** 691-695.

Hussain, M.B., M. Jahiruddin, R.H. Leoppert, G.M. Panaullah, M.R. Islam and J. M Duxbury. 2009. The effect of Iron Plaque and Phosphorous on yield and Arsenic accumulation in rice. *Journal of Plant Soil,* **317**: 167-176

Khan, P.M., Aslam, M.Y. Momen, M. Imtiaz, J.A. Shah and N. Depar. 2010. Determining the Nutritional Requirements of Rice Genotype JAJAL25/AEVOLED ANIA Tando Jam Pakistan. *Pakistan Journal of Botany*, **42(24):**3257-3263.

Mahajin, J.P., R.P. Singh and A.K. Dwivedi. 1994. Utilization of fertilizer Phosphorous by some rice varieties as influenced by phosphorous fertilization in black soil. J. Nucl. *Agric. Biol.*, **23(4):** 242-245.

Malik, D.M., B. Ahmed and M. Ahmed. 1984. Survey of soil fertility status and quality of ground waters in Punjab. Digest. 1981-84, Department of Agriculture, Lahore.

Matsua, T. K., Kumazawa, R. Ishii, K. Ishihara and H. Hirata 1995. Science of the plant. Food and Agriculture Policy Research Centre, Tokyo. Japan. pp. 1240.

Sahar, A. and N. Burbey. 2003. Effect of nitrogen, phosphorus and potassium (NPK) compound dosages on the growth and yield of lowland rice. *Journal of Stigma (Indonasia)*, **11(1):**26-29.

Sharif, M. M.S. Sarir and F. Rabi, 2000. Biological and chemical transformation of phosphorus in some important soil series of NWFP. *Sarhad Journal of Agricultural Research*, **16:** 587-592.

Shin, H.H. S. Shin, G.R. Dewbre and M. J. Harrison. 2004. Phosphate transport in Arabidopsis: Pht1;1 and Pht1;4 play a major role in phosphate acquisition from both low- and high-phosphate environments. *Plant Journal*, **39:** 629–642.

Steel, RGD. J.H. Torrie and D. Dickey. 1997. Principles and Procedure of Statistics. A Biometrical Approach 3rd Ed. McGraw Hill Book Co. Inc. New York. pp. 352-358.

Twyford, I. T. 1994. Fertilizer use and crop yields. Proc. 4th National Congress of Soil Science. Islamabad. pp: 47-71.