Potassium Nutrient Management in Wheat through 4R Nutrient Stewardship

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Abstract: In order to meet food requirement of expanding population, cereals yield must be increased. Wheat keeps prime importance in cereal crops of Pakistan. Despite of favorable cropping, this system suffers some weakness due to poor and timely nutrient management resulting in cereal's productivity loss. Present study was designed to executive the potassium nutrients in wheat cropping system using the 4R nutrient managing approach. The experiment was performed at two locations; one at the experimental site of the Department of Soil and Environmental Sciences, University of Sargodha and Government Research Farm Chakwal, using two wheat varieties (Punjab-2008 and Barani-2011). Treatments were arranged in randomized complete block design (RCBD) under factorial arrangement. Statistical analysis of the data was carried out by studying various yield parameters like plant height (maturity), number of tillers (m^{-2}), 1000 grain weight and grain yield (kg ha^{-1}). Least Significance Difference (LSD) test was applied to separate their means. As per results achieved from experiment, potassium source (SOP) applied as basal dose @ 80 kg ha^{-1} to wheat variety Punjab-2011, exhibited higher grain yield (2811 kg ha^{-1}) relevant to (MOP) where grain yield was attained (2711 kg ha^{-1}) applying same doses. On the other hand wheat variety Barani-2011 produced less response and produce (2611 and 2699 kg ha^{-1}) grain yield where SOP and MOP were applied at the same rate. Among the studied cultivars different sources (SOP and MOP) and rates (CKT, 1.5% and 3% solution) of K foliar application produced statistically similar results.

Keywords: Potassium fertilizer, split application, nutrient management, nutrient use efficiency.

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1. Introduction

Mineral fertilizers sustained agriculture throughout the world, resulting in food security for rapidly increasing population growth (Adnan et al., 2019; Nair, 2019; Stewart et al., 2005). Adding these in crop growth has fertile millions of hectares and converted barren land into cultivable (Comer et al., 2019; Balmford et al., 2005). However, imbalance use or excessive application of nutrients in crop production has environmental and agricultural consequences (Liu et al., 2015; Singh, 2000). Environmental drivers, rhizospheric constraints and management practices increases nutrient losses, leading to reduced nutrient use efficiencies and increased yield gaps of agricultural crops (Carciochi et al., 2020; Penuelas et al., 2012; Van Noordwijk and Cadisch, 2002). Moreover, nutrient losses potentially increases cost of crop production (Broberg et al., 2017). Thus, enhancing nutrient use efficiencies became one of the major priority of agricultural scientists (Fageria and Baligar, 2005; Salim and Raza, 2020; Shutz et al., 2018).

Among essential nutrients Potassium (K) is third major nutrient which plays pivotal role in protein synthesis, enzyme activation and photosynthesis (Hasanuzzaman et al., 2018 Prasad et al., 2019; Sustr et al., 2019; Zorb et al., 2014). Global potassium use efficiency for cereal crops is estimated to be 19%, which is lower than the use efficiency of nitrogen (33%), however slightly higher than phosphorus use efficiency (16%) (Dhillon et al., 2019). According to Chhibba, (2010) nearly 75-80% of K remained as residues of cereals, enabling them worth full source for farmers. In the view of Ladha et al. (2005) and

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Ghosh et al. (2015), nitrogen fertilizer application was found 30-50 percent and phosphorus was found 45% for crops production. Results of fertilizer catalyst application highlighted that its application significantly influenced the K mineral in soil surface (Thippeswamy et al., 2000).

The 4R Nutrient Stewardship framework offers four standards to consider for application of fertilizers in a responsible manner (Bryla, 2020). Key scientific principles used in 4R Nutrient Stewardship framework are right source, right rate, right time and right place to ensure uptake of nutrients in right amount, an appropriate time and reduce its losses (Mikkelsen et al., 2009; Phillips et al., 2009; Stewart et al., 2009; Wollmer-Sanders et al., 2016). Nutrient management in line with the 4R nutrient framework will potentially result in better crop yields and quality, reduced cost of production and required labor. Moreover it is also environment friendly with less soil degradation and nutrient losses especially leaching. All these advantages will conclude in better financial outputs (Bryla, 2020; Johnston and Bruulsema, 2014).

Although, Pakistani soils, in general, are rich in mica minerals, which are rich in potassium. However, it is not adequate for optimum growth of plants, mainly due to its poor availability for plant uptake (Wakeel et al., 2017). Fertilizer recommendations for K application essentially based on soil K retention properties (Arienzo et al., 2009; Askegaard and Eriksen, 2000; Jones, 2019). In Pakistan's farming system, there is limited application of potassium fertilizer. K due to high cost and erratic response of potassium application (Wakeel et al., 2017). This response can be attributed to unfavorable agroclimatic conditions, aggravated by imbalanced fertilizer application and inefficient nutrient management.

Improved nutrient management strategies aimed at efficient fertilizer use may help farmers to improve crop fertilization (Gandhi and Armstrong, 2016). Split application, including K, during cropping season reduces leaching losses, increases duration of K availability and uptake, leading to significant increase in nutrient use efficiency (Nkebiwe et al., 2016; Römheld and Kirkby, 2010; Thilakarathna and Raizada, 2015; Wu and Ma, 2015). Moreover, split K application improves crop yield and quality of agricultural crops (Annadurai et al., 2000; Lu et al., 2014), by enhancing sucrose supply and trigger the starch accumulation in grain (Limon-Ortega et al., 2020).

To boost up our crop production, basal and foliar application of K fertilization through wise use of 4-R nutrient management approach can enhance productivity and efficient nutrient management (Bruulsema et at., 2019; Flis and Jones 2019; Macintosh et al., 2019; Flis et al., 2018; Singh et al., 2017). Likewise, MOP is also an economic source of fertilization but it cannot be used in every condition. Some extra practices required for efficient use of the MOP, like right source, right time, right site application are quite promising in present scenario of using 4-R application. It is need of the hour to employ the considerable use of the MOP and SOP in the soil to evaluate the effectiveness of another 4-R strategy. That's why present study was designed to executive the potassium nutrients management in wheat cropping system using the 4R nutrient management approach under following principles:

Table 1. Key scientific principles used in 4R Nutrient Stewardship framework

Category	Scientific Principles
Right Source	Ensure a moderate supply of important nutrients, in view of both naturally existing sources and characteristics of specific products in plant available forms.
Right Rate	Identify supply of soil nutrients and plan needed.
Right Time	Highlight crop uptake dynamics, soil supply, and logistics for field operations. Regulate timing of nutrient risk loss.
Right Place	Diagnose root-soil dynamics. Manage spatial variability within the field to meet site specific crop needs. Limit potential losses from the field.

2. Materials and Methods

The Experiment was laid at two sites, identified as irrigated and rainfed climatic zone.

2.1. Site Description 1

The experiment was conducted at research farm area, Sargodha. Sargodha was situated at 32.07° N-72.68 ° E latitude at 189 m, altitude fall under semi-arid climate. The average day and night temperature during the study period was 10- 42.8°C. Two sources of K-MOP and SOP with three levels (Control, Medium, and High) were applied as basal and foliar application. Wheat (*Triticum aestivum* L) seed Punjab-2008 and Barani-2011 used to conduct this research was obtained from Punjab Seed Corporation Faisalabad, Pakistan. Randomized complete block design (RCBD) was used to arrange treatments on experimental plot size of 2.40m×6m, and experiment was conducted in triplicate.

Soil was prepared following local recommendations i.e., two cultivation followed by planking by tractor driven cultivator in all experimental plots. On 5th December, 100kg ha^{-1} seed was drilled in 22 cm apart of rows. Basal dose of N, P, and K fertilizers were applied at a rate of 60 and 25kg ha^{-1}, while nitrogen was applied at the rate of 110kg ha^{-1}(50 % at basal, 25% at initiation stage of crown root and 25% at flowering stage). All experimental plots were irrigated four times at initiation of crown root, tillering, flowerings and dough stage. At harvest maturity (20% moisture approximately) each experimental plot was manually threshed to calculate yield and yield parameters.

2.2. At Site 2

Another experiment was laid out at Adaptive Research Farm Chakwal, Punjab. Chakwal was situated at latitude 32.93º N – 72.86º E, 498 m altitude fall under semi-arid climate. The average day and night temperature during the study period was 22.3º. Experiment soil was sandy clay loam. Two sources of K-MOP and SOP with three levels (Control, Medium, and High) were applied as basal and foliar application. Same Wheat seed varieties Barani-2011 and Punjab-2008 obtained from Punjab Seed Corporation Faisalabad, Pakistan were cultivated. Randomized complete block design was used to lay out a plot size of 2.40m×6m with three replicates. Time of sowing, seed rate, land preparation and irrigations (Numbers and time of irrigation) were same as the trial laid out at the department of soil and environmental sciences, university of Sargodha. Likewise basal dose of N, P, and K fertilizers were applied at a rate of 60 and 25kg ha^{-1}, while Nitrogen was applied at the rate of 110kg ha^{-1} (50 % at basal, 25% at initiation stage of crown root and 25% at flowering stage).

Analysis of variance technique was used to analyze statistically significance of generated data. For comparison of treatment means Least Significance Difference (LSD) was also used (Jan et al., 2009; Arif et al., 2012).

3. Results

3.1. Plant height (cm)

Table 1 exhibited that wheat variety Punjab -2008 achieved maximum plant height (103 cm) where potassium source (MOP) was employed @ 40 kg ha^{-1} as basal dose, which is statistically at par with potassium source (SOP) at the same rate. The data also revealed that in some what plant height decreased when potassium sources (SOP+MOP) were applied @ 80kg ha^{-1} to both wheat varieties (Punjab-2008 and Barani-2011) as shown in Table 1.

Minimum plant height (97 and 97.5 cm) was obtained where no any source of potassium was applied which is statistically at par with treatment where no foliar spray of potassium was sprayed in both the locations (I and II) .When potassium sources (SOP+MOP) were applied as foliar @ 1.5% solution or 3% s spray has non-significant effect on plant height on both wheat varieties (Punjab 2008 and Barani-11) at both locations (I and II).

3.2. Number of tillers m^{-2}

Table 2 revealed significant differences among the treatments 4R regarding number of tillers m^{-2} of wheat variety Punjab-2008 instead of Barani-2011. In comparison of 4R of potassium source to wheat varieties, maximum no of tillers m-^{2} (363cm) were obtained when potassium source (SOP) was applied @ 80 kg ha^{-1} as basal dose with maximum rate which is statistically significantly different to control where potassium was applied @ 40 kg ha^{-1} (Table 2). In compression of right source (MOP) as basal dose showed non- significant appearance as basal dose when applied @ 40 kg ha^{-1}, 80 ha^{-1} and also in control. The similar trend of results was obtained in location-II.

Table 2. Plant height (cm) of wheat cultivars in response to levels and sources of potassium fertilizer application in irrigated area of Punjab. (Values are mean of three independent observations).

K Fertilizer	Basal K –Application						Foliar K –Application					
	Control		40 kg ha^{-1}		80 kg ha^{-1}		CKT		1.5%		3%	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
SOP	97 c	95 c	101 a	99a	100 ab	100 ab	97 c	94 d	98 c	96ab	99 ab	95c
MOP	97.5 c	94 d	103 a	95c	101 b	97ab	97 c	95 c	99 ab	96ab	99.5 ab	96.5a
Mean	97 C	94.5 C	102 A	97B	100.5 AB	98.5A	97 C	94.5 C	98.5 BC	96A	99.2 C	95.75B

SOP, sulphate of potash; MOP, murate of potash; control – without potash; CKT, without potassium solution; 3 level of K, control, medium and high; V1, Punjab-2008; V2, Barani-2011.

Table 3. Number of tillers (m^{-2}) of wheat cultivars in response to levels and sources of potassium fertilizer application in irrigated area of Punjab. (Values are mean of three independent observations).

K Fertilizer	Basal K –Application						Foliar K –Application					
	Control		40 kg ha^{-1}		80 kg ha^{-1}		CKT		1.5%K		3%K	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
SOP	280 c	275 d	310	291c	363 a	322 ab	281 c	270 d	290 ab	285 ab	291 a	290 a
MOP	282 c	276 d	306	301 b	353 ab	330 ab	283	275 c	289	286 ab	291 a	290 a
Mean	281C	275.5C	308B	296B	358A	326A	282C	272.5C	289.5B	285.5B	291A	290 A

SOP, sulphate of potash; MOP, murate of potash; control, without potash; CKT, without potassium solution; 3 level of K, control, medium and high; V1, Punjab. 2008; V2, Barani 2011.

In comparison of right place in 4R potassium applied basal k applied statistically significant as compared to foliar application (CKT, 1.5% Solution and 3% Solution) with maximum no of tillers m-2 (291 cm) were obtained when potassium was sprayed @ 3% potassium source (SOP) was sprayed. Which is statically at par with the source applied @15% Solution

Minimum no of tillers-1 in comparison of two wheat varieties were obtained (275 and 276 cm) where wheat variety Barani-2011 was sown under two potassium source (SOP and MOP) respectively (Table 2). Similar trend of result was obtained in location II. These finding are consistent with Ali et al. (2013) who summarized that adding suitable amount of potassium, growth and yield can be improved

3.3. 1000 grain weight (gm)

Table 3 highlighted significant differences among treatments 4R regarding 1000-grain Wt. of wheat variety Punjab-2008 as compared to Barani-2011. In comparison to potassium source maximum 1000-grain weight (40.2g) was obtained where MOP was applied @ 80g ha^{-1} to wheat variety Pb-2008 as compared to Barani-2011 and 1000-grain weight (36.70 g) was obtained where SOP was applied @ 80g ha^{-1} to wheat variety Pb-2008 as compared to Barani-2011. Potassium source (MOP and SOP) response to wheat variety Barani-2011 had non-significant effect, as compared to Punjab -2008 as basal applications.

In compression of right place in 4R determine applied as foliar applied it has statistically significant effect on 1000-grain yield of wheat variety Punjab -2008 as compared to Barani-2011.

Maximum 1000-grain weight (42.9 g) of wheat variety Punjab-2008 achieved when potassium source (MOP) was applied as foliar spray @ 3% solution. which was statistically at par with the potassium source (SOP) at the same rate of application, where average 1000-grain was recorded 38.3g) was obtained as compared to wheat variety Barani-2011where 1000- grain weight (37.9 and 36.40 g) was achieved respectively which are statistically at par with each other.

Data presented in Table 3 showed that minimum 1000-grain weight (32 g and 31g) was achieved in control treatment where no potassium (SOP and MOP) was applied as basal dose and (32.1 31.77g) achieved as foliar treatment of wheat variety Barani-2011, as compared to wheat variety Ph-2008 with respect to (34g and 35g) and (34.10 and 33.77g) 1000-grain weight obtained in both the locations respectively. These findings are in line with the conclusion of Khaliqui (1988) and Jan et al., (2012).

Table 4. 1000 -grain weight (g) of wheat cultivars in response to levels and sources of potassium fertilizer application in irrigated area of Punjab. (Values are mean of three independent observations).

K Fertilizer	Basal K –Application						Foliar K –Application					
	Control		40 kg ha^{-1}		80 kg ha^{-1}		CKT		1.5%K		3%K	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
SOP	34d	32d	38.5ab	34.5a	36.70c	33.70ab	34.10d	32.10d	37.8c	34.8c	38.3ab	36.40ab
MOP	35d	31d	38.10ab	33.10c	40.2a	34.02a	33.77d	31.77d	39.66ab	33.66c	42.9a	37.9a
Mean	34.5C	31.5C	38.3B	33.8B	38.45A	33.86A	33.935C	31.935C	38.73B	34.23B	40.6A	37.15A

SOP, sulphate of potash; MOP, murate of potash; control, without potash; CKT, without potassium solution; 3 level of K, control, medium and high; V1, Punjab. 2008; V2, Barani 2011.

Table 5. Grain yield (kg ha^{-1}) of wheat cultivars in response to levels and sources of potassium fertilizer application in irrigated area of Punjab. (Values are mean of three independent observations).

K Fertilizer	Basal K –Application						Foliar K –Application					
	Control		40 kg ha^{-1}		80 kg ha^{-1}		CKT		1.5%K		3%K	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
SOP	2465 e	2400 e	2715 c	2515 c	2811 a	2611 ab	2455 e	2410 d	2555 c	2555 c	2611 a	2588 a
MOP	2471 d	2410d	2615 c	2675 ab	2711 ab	2699 a	2466 d	2405 e	2577 c	2570 ab	2599 ab	2589 a
Mean	2468C	2405B	2665B	2595C	2761A	2655A	2460C	2407.5C	2562.5B	2562.5B	2605A	2588.5A

SOP, sulphate of potash; MOP, murate of potash; control, without potash; CKT, without potassium solution; 3 level of K, control, medium and high; V1, Punjab. 2008; V2, Barani 2011.

3.4. Grain yield (kg ha^{-1})

Table 4 indicated statistically substantial differences among the treatment of 4R regarding grain yield (Kg ha^{-1}) of two wheat varieties Punjab -2008 and Barani-2011 at different locations. Data discovered that maximum grain yield (2811 kg ha^{-1}) was obtained when potassium source (SOP) as basal application, was applied @ 80 kg ha^{-1} to wheat variety Punjab-2011, as compared to (MOP) where grain yield was obtained (2711 kg ha^{-1}) at the same doses. On the other hand wheat variety Barani -2011 gave less response and produce (2611 and 2699 kg ha^{-1}) grain yield where SOP and MOP were applied at the same rate.

K- nutrients as (SOP and MOP) when applied as foliar spray under three different treatments (CKT, 1.5% and 3% solution.) to both wheat varieties had no significant effect on grain yield to each other at (Location –I and II). Data presented in Table 5 showed that minimum grain yield (2465 and 2471 kg ha^{-1}) was obtained in treatment where no K- nutrient sources (SOP and MOP) were applied as basal application to wheat variety Punjab-2008 in Location-I. The similar trend of results was recorded in Location-II. These results were in accordance with the findings of Vengiell (1982), Hamayun et al., (2011) and Malik et al., (2018).

4. Conclusion

Conclusion made from this 4R nutrient experiment, that K–fertilizer (SOP) level 80 kg ha^{-1}, as basal application responded significantly on the wheat variety Punjab-2008. It was also observed that K- nutrients as (SOP and MOP) when applied as foliar spray under three different treatments (CKT, 1.5% and 3% solution) to both wheat varieties had no significant effect on grain yield , under the irrigated agro ecological conditions .

List of Abbreviations: RCBD, Randomized Complete Block Design; LSD, Least Significant Difference; MOP, Murate of Potash; SOP, Sulphate of Potash.

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Author's Contribution: R. H. designed the study and conducted the experiment under the supervision of T. A. M. & A. G. M. T. helped in performing statistical analysis while R. H. wrote the manuscript with the help of M. T. Finally, T. A. M. approved the current version of manuscript. All the authors read and approved the final manuscript.

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