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Potassium fertilization to augment growth, yield attributes and yield of dry direct seeded basmati rice (*Oryza sativa*)

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ABSTRACT

The effect of potassium (K) application based on 4R stewardship (right rate, time, method, and source) on growth, yield attributes and yields of dry direct seeded basmati rice (*Oryza sativa* L.) was evaluated during rainy (*kharif*) season of 2015 and 2016 at IARI, New Delhi. Application of recommended dose of K (60 kg/ha), half as basal and remaining half at panicle initiation (PI) stage increased the grain (5.4 t/ha) and straw yields (7.65 t/ha) by 10 and 4% respectively, over applying the full dose as basal. A strong, positive and significant correlation was observed between yield attributes [panicle weight (r^2=0.79), panicle length (r^2=0.83), fertility % (r^2=0.84)] and yield of dry direct seeded basmati rice. Similarly, positive and significant correlation was observed between leaf area index at 60 DAS (r^2=0.73) & 90 DAS (r^2=0.91) and dry matter production. The two foliar sprays of 2.5% potassium nitrate (1st at active tillering, and 2nd at panicle initiation) increased fertility (83.5%) and grain yield (4.3 t/ha) by 6% and 8% respectively, over control. However, the combined application of foliar sprays and two split application of recommended dose of K showed non-significant effect on growth, yield and yield attributes. Thus, to obtain higher yield in dry direct seeded basmati rice, application of 60 kg/ha, half as basal and remaining half at panicle initiation (PI) is recommended.

Key words: Basmati rice, Dry direct seeding, Economics, Growth analysis, Potassium, Yield

The major issues associated with sustainability of rice (*Oryza sativa* L.)-based cropping systems are soil health degradation, declining underground water table, yield stagnation and environmental pollution (Bhatt *et al.* 2016). Surveys in the Indo-Gangetic Plains (IGP) revealed that farmers often apply more than recommended dose of N and P fertilizer, but ignore the application of other nutrients in required quantity (Singh *et al.* 2005). As a result, the K balance in rice-wheat (R-W) cropping system is negative. The mining of K is more in intensively cultivated areas because of higher productivity and burning of rice straw (Bijay-Singh *et al.* 2003).

Production of basmati rice in Indo-Gangetic Plains is water, energy, capital and labour intensive. It has been reported that water availability to agriculture is expected to reduce from 72% in 1995 to 62% by 2020, globally and from 87% to 73% in developing countries (Khan *et al.* 2006). Hence, development and adoption of water saving technologies in rice is very essential. Direct seeded rice (DSR) has the potential to save up to 50% water requirement of rice (Singh and Chinnasamy 2007). However, DSR is more prone to negative K balance since it does not receive sufficient irrigation water, which can otherwise add certain amount of K to the soil (Vijayakumar *et al.* 2019). In addition, availability of K is reduced in DSR as compared to conventional system. The supply of plant nutrients especially K based on 4R nutrient stewardship in dry directed seeded rice may help in sustaining the productivity of R-W cropping system besides saving irrigation water. Keeping this in view, a field experiment was conducted to study the effect of rate, method, time and source of K fertilization on growth, yield and economics of dry directed basmati rice grown in IGPs.

MATERIALS AND METHODS

Field experiment was conducted during *kharif* season of 2015 and 2016 at research farm of ICAR-Indian Agricultural Research Institute (IARI), New Delhi. The soil of experimental plot was sandy clay loam in texture with *p*H 7.5, EC (0.32 dS/m), OC (0.55%), available N-201 kg/ha (Subbiah and Asija 1956), available P-12.8 kg/ha (Olsen *et al.* 1954) and available K-213.8 kg/ha (1 N NH_4OAc-extractable K) (Hanway and Heidel 1952). The experiment was conducted in randomized block design with

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12 treatments and replicated thrice. The treatment details are given in Table 1. Rice cultivar Pusa Basmati 1509 was sown using seed drill. The recommended dose of N (120 kg/ha) was applied in 3 splits by applying 1/3rd at 10 DAS (days after sowing), 1/3rd at tillering (40 DAS) and remaining 1/3rd at panicle initiation stage (70 DAS). The full dose of phosphorus (60 kg/ha) was applied as basal and it was incorporated into the soil while sowing by seed drill.

Data of plant height was collected at 30 days interval from 5 randomly selected plants using wooden scale from the ground surface to the tip of the tallest leaf and the mean value was considered for analysis. Using a leaf area meter (Model LICOR 3000, USA), the area of fresh green leaves (five plant leaves) was measured and expressed in cm^2/plant.

Table 1 Treatments details

Treatment		Treatment details	K_2O (kg/ha)
T_1	No K	No potassium application in both the year	0
T_2	100% basal (B)	Entire recommended dose of potassium (RDK) was applied at the time of sowing in both the year through muriate of potash (MOP)	60
T_3	50% B	50% of the RDK was applied at the time of sowing in both the year through MOP	30
T_4	50% B+50% PI	50% of the RDK was applied at the time of sowing, remaining 50% applied at panicle initiation (PI) stage in both the year through MOP	60
T_5	75% B+25% PI	75% of the RDK was applied at the time of sowing, remaining 25% applied at PI stage in both the year through MOP	60
T_6	2 FS	Two foliar spray (FS) of 2.5% KNO_3 [1st FS @ active tillering (AT), 2nd FS @ PI]	8.8
T_7	100% B+2 FS	Basal application of 100% RDK at the time of sowing + 2 FS of 2.5 % KNO_3 [1st FS @ AT, 2nd FS @ PI]	68.8
T_8	50% B+2 FS	Basal application of 50% RDK at the time of sowing + 2 FS of 2.5 % KNO_3 [1st FS @ AT, 2nd FS @ PI]	38.8
T_9	75% B+2 FS	Basal application of 75% RDK at the time of sowing + 2 FS of 2.5 % KNO_3 [1st FS @ AT, 2nd FS @ PI]	53.8
T_{10}	50% B+25% PI+ 2 FS	Basal application of 50% RDK at the time of sowing + 50% RDK at PI + 2 FS of 2.5% KNO_3 [1st FS @ AT, 2nd FS @ PI]	68.8
T_{11}	75% B+25% PI+ 2 FS	Basal application of 75% RDK at the time of sowing + 25% RDK at PI +2 FS of 2.5 % KNO_3 [1st FS @ AT, 2nd FS @ PI]	68.8
T_{12}	150% B	150% RDK was applied at the time of sowing in both the year	90

$$\text{LAI} = \frac{\text{Total leaf area (cm}^2\text{)/plant}}{\text{Ground area (spacing cm}^2\text{)/plant}}$$

For dry weight the collected plant sample (25 cm × 25 cm area) were dried in shade about one week then oven dried at 65±5ºC for one day. The dry weight was recorded with the help of electronic balance and expressed in g/m^2. The mean CGR, RGR and NAR was worked out with the standard formulas given by Watson *et al.* (1952) and expressed as g/m^2 land area/day, mg/g dry matter/day and g/m^2 leaf area/day respectively.

The number of tillers/m^2 was calculated by counting total number of tillers in 0.5 m×0.5 m quadrate at the time of grain filling and it was converted to per m^2 area. The panicle length and weight of five selected plant was measured using wooden scale and electronic balance respectively. The number of grains per panicle was calculated by counting the total number of grains in the five randomly collected panicle. Similarly, filled and unfilled (chaffy) grains per panicle was counted and the fertility percentage was computed by using the following formula

$$\text{Fertily percentage} = \frac{\text{Number of filled grains/panicle}}{\text{Total number of grains/panicle}} \times 100$$

All the data were subjected to one-way analysis of variance (ANOVA) using the general linear model procedures of the Statistical Analysis System (SAS Institute, Cary, NC). The F-test was used to determine significant effects of potassium fertilizer and least significant difference (LSD) was used to compare means.

RESULTS AND DISCUSSION

Growth parameters: The highest plant height (Table 2) was recorded in T_{12} (150% B) which remained at par with T_2, T_8, T_4, T_5, T_{10} and T_{11}. The lowest plant height was recorded in T_1. The plant height was found between the ranges of 89 to 102 cm. Similar to plant height the dry matter production is increased up to harvest of the crop. The dry matter production was found non-significant up to 30 DAS and after that it was found significant up to harvest of the crop. Among the treatment T_7 (100% B + 2FS) recorded the maximum dry matter production at 60 and 90 DAS, which remained at par with T_4, T_5, T_{10} and T_{11} at 90 DAS. At harvest the maximum dry matter production was recorded in T_{10} (50% B + 50% B + 2 FS) which remained at par with T_4, T_5, T_7, T_{10}, T_{11}. During all the intervals the lowest dry matter production was recorded in treatment T_1. Application of K stimulate the root growth (Fageria and Oliveira 2014) and increases the surface area contact, which intern increases availability of water and nutrients (Tang *et al.* 2015). Thus the increase in water and nutrient availability might have increased the plant height and dry matter production.

The LAI of was between 3.79–4.93 (Table 2). At 60 DAS the highest LAI was recorded in T_{11} which remained at par with most of the treatments except T_1, T_3 and T_8.

Table 2 Effect of K application on growth parameters of dry directed basmati rice (2 year pooled data)

Treatment	Plant height (cm)				Dry matter (g/m^2)				Leaf area index		
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS
T_1	30	57^{C}	86^{D}	89^{D}	66	338^{F}	917^{D}	1071^{E}	0.83	1.83^{E}	3.79^{F}
T_2	31	65^{A}	98^{A}	101^{A}	68	398^{AB}	1127^{B}	1276^{D}	0.93	2.35^{AB}	4.50^{CD}
T_3	31	61^{ABC}	88^{CD}	94^{BCD}	67	362^{DE}	1071^{BC}	1148^{E}	0.91	2.13^{CD}	4.26^{DE}
T_4	31	62^{AB}	96^{AB}	99^{AB}	67	378^{CD}	1232^{A}	1414^{AB}	0.89	2.38^{A}	4.80^{ABC}
T_5	31	63^{AB}	97^{A}	99^{AB}	68	384^{BC}	1231^{A}	1409^{AB}	0.92	2.40^{A}	4.75^{ABC}
T_6	30	59^{BC}	89^{BCD}	92^{CD}	66	352^{EF}	1020^{C}	1112^{E}	0.87	2.03^{D}	4.10^{EF}
T_7	32	65^{A}	98^{A}	102^{A}	68	408^{A}	1287^{A}	1440^{AB}	0.92	2.37^{A}	4.87^{AB}
T_8	31	62^{AB}	93^{ABC}	96^{ABC}	68	371^{CD}	1130^{B}	1264^{D}	0.88	2.24^{BC}	4.55^{BCD}
T_9	31	64^{A}	96^{AB}	99^{ABC}	68	382^{BC}	1248^{A}	1364^{BC}	0.90	2.38^{A}	4.82^{ABC}
T_{10}	31	63^{AB}	97^{A}	102^{A}	67	383^{BC}	1251^{A}	1469^{A}	0.90	2.41^{A}	4.92^{A}
T_{11}	31	64^{A}	98^{A}	102^{A}	68	381^{BC}	1252^{A}	1458^{A}	0.91	2.42^{A}	4.93^{A}
T_{12}	32	65^{A}	99^{A}	102^{A}	68	408^{A}	1120^{B}	1286^{CD}	0.94	2.36^{AB}	4.54^{BCD}
SE(d)	1.56	2.28	3.23	3.15	6.47	8.78	43.93	41.76	0.04	0.06	0.16
LSD (P=0.05)	NS	4.74	6.69	6.54	NS	18.21	91.11	86.60	NS	0.12	0.33

Note: Means followed by a superscripted similar letter within a column are not significantly different (at $P < 0.05$) according to LSD test.

Similarly, at 90 DAS, the highest LAI was recorded in T_{11} which remained at par with T_{10}, T_4, T_5, T_7 and T_9. At all the intervals the lowest LAI was recorded in T_1. The study of correlation between LAI and dry matter production of basmati rice during 60 DAS (r^2=0.73) and 90 DAS (r^2=0.91) shows strong positive and significant correlation (Fig 1 a, b). In our study the highest LAI was recorded in treatments were K was supplemented in later stage either through foliar spray or splits application. The LAI indicates the size of the assimilatory system of the crop. Thus the higher LAI might have increased the solar radiation interception and subsequently photosynthesis. The deficiency of K in T_1, T_3 and T_6 reduces the fixation of CO_2, transport and utilization of photosynthates, which eventually reduced the crop yield (Pettigrew 2008).

Yield attributes: The highest panicle length and panicle weight was recorded in treatment T_7 (100% B + 2 FS) which remained at par with T_4, T_5, T_9, T_{10} and T_{11} (Table 3). The panicle length and panicle weight of dry direct seed basmati rice was found between the ranges of 26.2-28.9 cm and 1.95-2.82 g respectively. The maximum number of grains/panicle and filled grains/panicle was recorded in T_{10} (50% B + 50% PI + 2 FS), which remained at par with T_4, T_5, T_7, T_9, T_{11} and T_{12}. The total number of grains/panicle

Table 3 Effect of K application on yield attributes of dry directed basmati rice (2 year pooled data)

Treatments	Panicle length (cm)	Panicle weight (g)	Total grains/ panicle (No.)	Filled grains/ panicle (No.)	Fertility (%)	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index
T_1	26.2^{C}	1.95^{D}	103.7^{D}	78.7^{D}	75.9^{I}	24.3^{C}	3.98^{D}	6.69^{C}	37.2^{D}
T_2	27.4^{B}	2.41^{BC}	108.0^{BCD}	95.0^{B}	88.0^{E}	26.0^{AB}	4.90^{B}	7.39^{AB}	39.9^{ABC}
T_3	27.1^{B}	2.21^{C}	105.0^{D}	87.0^{C}	82.9^{H}	25.6^{ABC}	4.45^{C}	6.89^{C}	39.2^{BC}
T_4	28.6^{A}	2.76^{A}	111.9^{ABC}	103.7^{A}	92.4^{D}	26.8^{AB}	5.42^{A}	7.65^{AB}	41.5^{A}
T_5	28.6^{A}	2.76^{A}	113.0^{AB}	105.0^{A}	92.9^{CD}	26.7^{AB}	5.40^{A}	7.67^{AB}	41.4^{A}
T_6	27.2^{B}	2.21^{C}	103.2^{D}	86.7^{C}	83.5^{G}	25.4^{BC}	4.31^{CD}	6.80^{C}	38.8^{CD}
T_7	28.9^{A}	2.84^{A}	112.8^{AB}	105.8^{A}	93.8^{B}	26.9^{A}	5.42^{A}	7.62^{AB}	41.6^{A}
T_8	27.4^{B}	2.35^{BC}	107.3^{CD}	94.3^{B}	87.9^{E}	26.5^{AB}	4.90^{B}	7.31^{B}	40.1^{ABC}
T_9	28.7^{A}	2.74^{A}	111.3^{ABC}	103.8^{A}	93.3^{BC}	26.7^{AB}	5.42^{A}	7.65^{AB}	41.5^{A}
T_{10}	28.8^{A}	2.79^{A}	113.2^{A}	105.7^{A}	93.4^{BC}	26.6^{AB}	5.44^{A}	7.65^{AB}	41.5^{A}
T_{11}	28.8^{A}	2.82^{A}	111.5^{ABC}	105.8^{A}	94.8^{A}	26.8^{AB}	5.45^{A}	7.70^{A}	41.4^{A}
T_{12}	27.4^{B}	2.43^{B}	110.2^{ABC}	95.7^{B}	86.9^{F}	26.3^{AB}	5.09^{AB}	7.39^{AB}	40.8^{AB}
SE(d)	0.23	0.10	2.43	2.43	0.29	0.70	0.178	0.175	0.858
LSD (P=0.05)	0.47	0.20	5.04	5.04	0.61	1.44	0.369	0.362	1.778

Note: Means followed by a superscripted similar letter within a column are not significantly different (at $P< 0.05$) according to LSD test.

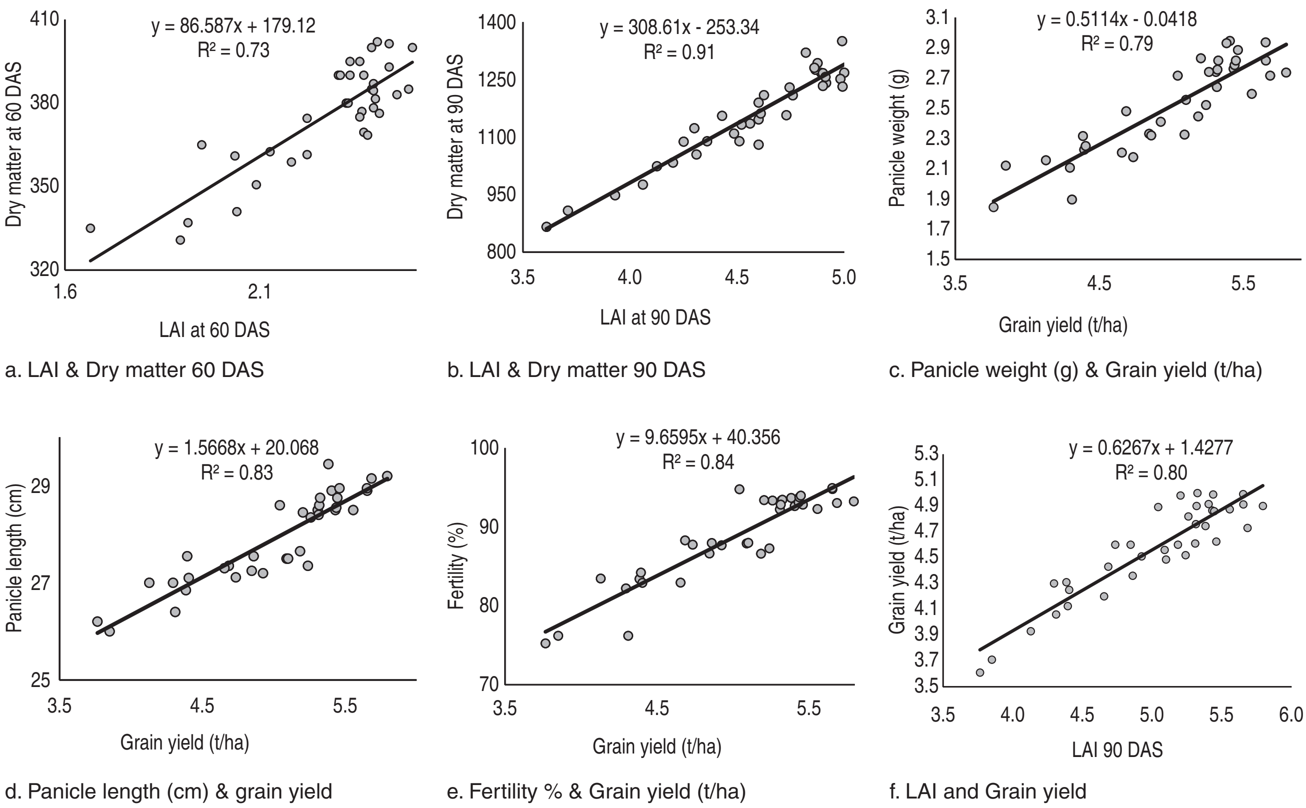

Fig 1 Relationship between LAI & dry matter at 60 DAS (a), LAI & Dry matter at 90 DAS (b), panicle weight & grain yield (c), panicle length (cm) & grain yield (d), fertility % & grain yield (e), LAI & grain yield (f).

and filled grains/panicle were found between the ranges of 103.7 to 113.2 and 78.7 to 105.8 (Nos) respectively. The lowest panicle length, panicle weight, grains/panicle and filled grains/panicle were recorded in T_1. Among the treatments T_{11} recorded the highest fertility percentage of 94.8%, whereas T_1 recorded the lowest of it (75.9%). The fertility percentage of rice was found between the ranges of 75.9 to 94.8%. The split application of RDK increased the fertility percentage by 22% over control. Treatment T_6 (2 FS) increased fertility percentage of direct seeded basmati rice by 6% (83.5%) over T_1. It clearly shows that fertility percentage of rice increased by foliar spray and top dressing of K at PI. Among the treatments the highest test weight was recorded in T_7 which remained at par with all the treatments except T_1. The test weight of rice was in the range of 24.3–26.8 g. K has role in pollen germination, development as well as seed development. Thus external application of K might have increased the fertility percentage by increasing pollen germination and development. The similar results of increased fertility percentage of rice by foliar sprays and top dressing of K was also reported by Lv *et al.* (2017).

Yield: The grain and straw yield was between 3.98–5.45 t/ha and 6.69– 7.70 t/ha respectively (Table 3). The treatment T_{11} (75% B + 25% PI + 2 FS) recorded the highest grain and straw yield which remained at par with T_4, T_5, T_7, T_9 and T_{10}. Treatments viz., T_4, T_5, T_7, T_9, T_{10} and T_{11} increased the grain yield by 10 and 21% over T_2 and T_3 respectively. However, the highest straw yield was at par with T_2 and T_{12}. It shows insufficient supply of K in T_2 and T_3 that reduced grain yields, whereas the straw yield of dry direct seeded basmati rice was not much affected by K supply. The yield difference between T_1 and T_6 (2 FS) is statistically significant, as T_6 (2 FS) increased grain yield by 8% over T_1. It shows that in the absence of K application, two foliar sprays of KNO_3 could increase the grain yield of basmati rice. However, basmati rice yield was not increased if foliar spray is combined with split application of RDK. The relative yield increased per unit of K application was highest in T_6 (2 FS), whereas T_{12} recorded the lowest of it. The range of harvest index of rice was 37.2–41.6. The treatments T_4, T_5, T_7, T_9, T_{10} and T_{11} increased the harvest index of basmati rice by 4 and 6% over T_2 and T_3 respectively. The study of correlation between yield attributes [panicle weight (r^2=0.79), panicle length (r^2=0.82), fertility % (r^2=0.84)] and yield showed a strong positive and significant correlation (Fig 1 c, d, e). Similarly, correlation between LAI and grain yield showed positive and significant correlation (r^2=0.82) (Fig 1 f).

Based on two year experimental results, it is suggested that, to gain higher productivity, profitability in direct seeded basmati rice, 60 kg K_2O should be applied in two equal splits (50% B + 50% PI or 75% B + 25% PI). In case of the absence of basal application of K, two foliar sprays (1st active tillering, 2nd panicle initiation) of 2.5% KNO_3 were found to increase yield and profitability of direct seeded basmati rice. Among the growth stages, panicle initiation stage was found to be most critical for K supply, and insufficient supply of K during PI stage decreased the fertility percentage of direct seeded basmati rice and subsequently the grain yield.

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