



## Productivity enhancement and biofortification of maize (*Zea mays*)- wheat (*Triticum aestivum*) cropping system through integrated potassium management

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### ABSTRACT

A field experiment was conducted during the *kharif* and *rabi* seasons of 2010-11 and 2011-12 at Indian Agriculture Research Institute, New Delhi to find out the performance of maize (*Zea mays* L.) – wheat (*Triticum aestivum* L.) cropping system with integrated potassium management through muriate of potash and farmyard manure. The experiment was laid out in randomized block design consisted of ten treatments and replicated thrice. Results revealed that all the treatment with potassium irrespective of sources significantly increased grain yield and nutrient concentration in grain of maize and wheat. The application of 60 kg K through muriate of potash + 30 kg K through farmyard manure resulted into highest grain yield of maize (4.44 and 5.42 tonnes/ ha) and wheat (5.39 and 5.49 tonnes/ ha). All treatment applied with farmyard manure shows higher macro – micro nutrient concentration in grain over control. The application of 60 kg potassium supplemented as 30 kg K through MOP and 30 kg K through farmyard manure in maize and application of 60 kg K through MOP alone in wheat resulted into highest system productivity (7.82 and 8.81 tonnes/ha).

**Key words:** Biofortification, Farmyard manure, Iron, Integrated potassium management  
Muriate of Potash, Nutrient concentration, Wheat equivalent yield, Zinc

Maize (*Zea mays* L.) crop regards as a queen of cereals occupies a pride place among cereal crops in India. It has emerged as third most important food crop after rice and wheat (*Triticum aestivum* L.) as it contributes around 24 per cent of total cereal production (Singh *et al.* 2011). Since rice, wheat and maize are staple crops with high consumption, any increase in mineral nutrient content might have significant effect on human nutrition throughout the world (Gunes *et al.* 2007). Micronutrient malnutrition is one of the attention drawing problems in the developing world. In India, about 230 million people are estimated to be undernourished, that account for more than 27 % of the world's undernourished population (Chakraborti *et al.* 2011). Biofortification is a recent approach aimed at increasing the bio-available nutrients, such as Fe and Zn, in these staple crops rather than using fortificants or supplements (Waters and Sankaran 2011, White and Broadley 2005). Potassium (K) is among the most essential nutrients for plant growth and large amounts are taken from the root zone for the production of most of the crops (Steingrobe and Claassen 2000). Potassium is very crucial for its interaction both antagonistic and synergistic with essential

macro and micro nutrients (Dibb and Thomson 1985). The removal of K by plants has been observed to be comparatively higher than the removal of nitrogen but the consumption ratio of N: K<sub>2</sub>O is 7:1 (Maene 2001). A continuous mismatch between nutrient removal and replenishment has been observed in various cropping systems even at the recommended levels of fertilizer application (Yadav *et al.* 1998). Nambiar and Ghosh (1984) indicated that after 8-11 years of continuous cropping, available potassium in soils declined under most of the long term fertilizer experiments where potassium was not applied. In plots receiving N and P, the drop in available K was faster in the initial years than in the later years. There is a growing evidence of increasing deficiency of K as a result of imbalanced use of N and P. Even under optimum rates of NPK application in long term experiments, the K balance under most of the soil and cropping systems was negative. The results of long term experiments clearly demonstrated that mining of soil K occurred with NP and even with NPK application. The reports on maize-wheat cropping system on alluvial soil at Ludhiana indicated that the system started drawing non-exchangeable K when exchangeable K fell below the critical limits. Thus, very low K fertility status of the soils started limiting the responses to N and P (Singh and Swarup 2000).

Keeping the above facts in view about synergistic role of potassium on translocation, uptake and accumulation of macro and micro nutrients in grain, the present study was

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carried out to investigate the effect of integrated K management on bio-fortification of grain and yield improvement in maize - wheat cropping system.

#### MATERIALS AND METHODS

Field experiments were conducted during rainy (*kharif*) and winter (*rabi*) seasons of 2010-11 and 2011-12 at Research Farm of Indian Agricultural Research Institute, New Delhi situated in north western India (28.35 N, 77.12' E) and at 228.6 m above msl. The experiment on maize - wheat cropping system was carried out in randomized block design with three replications and ten treatment combinations under different sets of treatment for both maize in *kharif* and wheat in *rabi* season at fixed site. The soil was sandy loam with pH 8.0, organic carbon 0.4%, medium in available N 173.2 kg /ha by alkaline permanganate method, P 13.8 kg /ha and K 261 kg/ha was estimated by Flame photometer. Recommended dose of 150 kg N/ha and 26 kg P/ha were applied to maize through urea and DAP, respectively. The full dose of P, K and 50 kg N/ha were given as basal and remaining 100 kg N/ha was given as 50 kg N/ha each at 30 days after sowing (DAS) in 1<sup>st</sup> split and 50 kg N/ha was given in 2<sup>nd</sup> split at 60 DAS. Muriate of potash (MOP) and farmyard manure (FYM) were used as sources of potassium and applied as per treatments. The nitrogen and phosphorus content of DAP and FYM were compensated in all the treatments by adjusting amount of urea and DAP. In wheat, the recommended dose of P, K and 60 kg N/ha were given as basal and remaining 60 kg N/ha was given as 30 kg N/ha each at 30 days after sowing (DAS) in 1<sup>st</sup> split and 30 kg N/ha in 2<sup>nd</sup> split at 60 DAS. Similarly, potassium was applied as per treatments: No K to maize and wheat – K<sub>0</sub> (M) – K<sub>0</sub> (W), 60 kg K/ha through MOP in maize and no K in wheat – MOP<sub>60</sub> (M) – K<sub>0</sub>(W), 30 kg K through MOP and 30 kg K through FYM in maize and 60 kg K through MOP in wheat – MOP<sub>30</sub> + FYM<sub>30</sub>(M) – MOP<sub>60</sub> (W), 60 kg K through MOP and 30 kg K through FYM in maize and no K in wheat – MOP<sub>60</sub> + FYM<sub>30</sub> (M) – K<sub>0</sub> (W), 30 kg K through MOP and 30 kg K through FYM in maize and no K in wheat – MOP<sub>30</sub> + FYM<sub>30</sub> (M) – K<sub>0</sub> (W), no K in maize and 60 kg K through MOP in wheat – K<sub>0</sub> (M) – MOP<sub>60</sub> (W), no K in maize and 30 kg K through MOP and 30 kg K through FYM in wheat – K<sub>0</sub> (M) – MOP<sub>30</sub> + FYM<sub>30</sub> (W), 60 kg K through MOP in maize and 30 kg K through MOP and 30 kg K through FYM in wheat – MOP<sub>60</sub> (M) – MOP<sub>30</sub> + FYM<sub>30</sub> (W), 60 kg K through MOP in maize and 60 kg K through MOP in wheat – MOP<sub>60</sub> (M) – MOP<sub>60</sub> (W), no K in maize and 60 kg K through MOP and 30 kg K through FYM in wheat – K<sub>0</sub> (M) – MOP<sub>60</sub> + FYM<sub>30</sub> (W). All the nutrients were given by broadcast and thoroughly mixed in the soil before sowing. The variety chosen were PEHM 2 for maize and HD 2967 for wheat. The spacing adopted was 60 cm × 20 for maize cm and 22.5 cm row spacing for wheat. The seed rate used for maize was 20 kg/ha and wheat 100 kg/ha.

At maturity plants of maize and wheat in an area of 4.8

and 4.5 m<sup>2</sup> from the centre of each plot were harvested manually. Dry weights of stems and grains were determined after separation. The aboveground biomass/ha was calculated based on the dried plant samples. The yield/ha was calculated based on the dried plant samples. After grinding, the dried material was analyzed for nitrogen phosphorus and potassium in grain and stover/straw samples of maize and wheat for total nitrogen uptake by following standard procedure (Prasad *et al.* 2006). After harvest of each crop the soil was analyzed for available nutrients following standard procedures.

Total productivity of the system in wheat equivalent yield was calculated on the basis of support price for the main produce during 2010-11 and 2011-12 and prevailing market prices for the inputs. The experimental data were statistically analyzed for the differential effect of treatments by applying "Analysis of Variance" (ANOVA) technique for randomized block design in both cases of maize and wheat as per the standard procedures.

#### RESULTS AND DISCUSSION

##### *Yield of maize and wheat*

All the treatments applied with K showed significant superiority over no K treatments for grain yield in maize and wheat during both years 2010-11 and 2011-12 (Table 1). In case of stover yield maize followed the same trend as grain yield, whereas difference in wheat straw yield was found non-significant. The treatment MOP<sub>60</sub> + FYM<sub>30</sub> (M) – K<sub>0</sub> (W) recorded higher grain yield of maize (4.44 tonnes/ha and 5.42 tonnes/ha) over all other treatments during both the years. The treatment MOP<sub>60</sub> + FYM<sub>30</sub> (M) – K<sub>0</sub> (W) was closely followed by treatment MOP<sub>30</sub> + FYM<sub>30</sub> (M) – MOP<sub>60</sub> (W) and MOP<sub>30</sub> + FYM<sub>30</sub> (M) – K<sub>0</sub> (W) which were found at par with each other and significantly superior over application of 60 kg K through MOP alone and treatment with no potassium.

Highest grain and straw yield of wheat was obtained with the application of 90 kg K/ha, supplemented 60 kg K through MOP + 30 kg through FYM, in the treatment K<sub>0</sub> (M) – MOP<sub>60</sub> + FYM<sub>30</sub> (W). Application of 60 kg K/ha supplemented with 30 kg K through MOP + 30 kg K through FYM was at par with 90 kg K, supplemented 60 kg K through MOP + 30 kg K through FYM and 60 kg K/ha through MOP alone. Application of MOP<sub>30</sub> + FYM<sub>30</sub> (M) – MOP<sub>60</sub> (W) was also found at par with treatment receiving 90 kg K supplemented 60 kg K/ha through MOP + 30 kg through FYM during both the years of experimentation. Same trend was observed in grain yield during 2011-12.

Potassium is vital to many plant processes including photosynthesis, translocation of photosynthates, protein synthesis, activation of plant enzymes, etc. The significant improvement in yield of wheat and maize was observed due to addition of 60 kg K through MOP and 30 kg K through FYM followed by application of 30 kg K through FYM and 30 kg K through MOP compared to 60 kg K through MOP alone. FYM supplies N, P and K in available forms to the plants through biological decomposition along

Table 1 Effect of integrated potassium fertilization on yield (tonnes/ha) of maize, wheat and system productivity of maize- wheat cropping system

Treatment	Maize				Wheat				Wheat equivalent yield (tonnes/ha)	
	Grain		Stover		Grain		Straw		2010–	2011–
	2010	2011	2010	2011	2010–	2011–	2010–	2011–	2010–	2011–
K <sub>0</sub> (M) – K <sub>0</sub> (W)	2.21	2.72	4.48	5.26	3.80	3.89	7.30	7.59	5.53	5.98
MOP <sub>60</sub> (M) – K <sub>0</sub> (W)	3.06	4.07	5.07	6.33	4.10	4.18	7.75	8.06	6.49	7.31
MOP <sub>30</sub> +FYM <sub>30</sub> (M) – MOP <sub>60</sub> (W)	3.68	4.89	5.90	6.75	4.94	5.05	8.13	8.53	7.82	8.81
MOP <sub>60</sub> + FYM <sub>30</sub> (M) – K <sub>0</sub> (W)	4.44	5.42	6.53	7.03	4.22	4.31	7.78	8.09	7.70	8.48
MOP <sub>30</sub> + FYM <sub>30</sub> (M) – K <sub>0</sub> (W)	3.72	4.82	5.83	6.62	4.10	4.19	7.76	8.07	7.00	7.89
K <sub>0</sub> (M) – MOP <sub>60</sub> (W)	2.21	2.96	4.54	5.64	4.78	4.95	7.86	8.17	6.51	7.13
K <sub>0</sub> (M) – MOP <sub>30</sub> + FYM <sub>30</sub> (W)	2.21	3.02	4.39	5.72	5.15	5.25	8.18	8.66	6.88	7.58
MOP <sub>60</sub> (M) – MOP <sub>30</sub> + FYM <sub>30</sub> (W)	2.99	4.30	5.14	6.53	5.05	5.16	8.14	8.77	7.39	8.47
MOP <sub>60</sub> (M) – MOP <sub>60</sub> (W)	3.02	4.21	5.21	6.43	4.81	5.01	7.93	8.24	7.17	8.12
K <sub>0</sub> (M) – MOP <sub>60</sub> +FYM <sub>30</sub> (W)	2.21	3.20	4.47	5.83	5.39	5.49	8.20	8.98	7.11	7.95
LSD(P=0.05)	0.46	0.51	0.44	0.71	0.5	0.6	NS	NS	0.63	0.67

\*Selling price for maize ₹ 9 000/tonne and 10 000/tonne and wheat 11 500/ tonne and 13 000/ tonne dsuring 2010-11 and 2011-12, respectively

with micronutrients in proper ratio, which resulted into higher yields. Sharma and Subehia (2003) reported that integrated use of FYM with balanced chemical fertilizers gave higher yield compared to 100% NP and 100% NPK fertilizers. Mumtaz (2009) and Tabatabaii *et al.* (2011) reported that increased application of K increase grain yield which was attributed due to greater number of grains/cob and 1 000 grain weight in maize. Rehman *et al.* (2008) reported that different levels of NPK and FYM alone or in combination had significant effect on spikes/m<sup>2</sup>, grains/spike, biological yield and thousand grain weight. Farmyard manure at 45 tonnes/ha produced the maximum spikes/m<sup>2</sup> (191.2), grains/spike (54.4), thousand grain weight (34.6 g) and biological yield (10 tonnes/ha) in wheat crop.

#### System productivity

System productivity in wheat seed equivalent yield was marginally higher in second year compared to the first year (Table 1). During both the year all the treatments applied with K found significantly superior over treatment applied with no K. Highest system productivity was recorded under treatment MOP<sub>30</sub>+FYM<sub>30</sub>(M) – MOP<sub>60</sub>(W) followed by MOP<sub>60</sub>+ FYM<sub>30</sub>(M) – K<sub>0</sub>(W). Treatments applied with FYM showed better system productivity compared treatment applied with K though MOP alone. It might be due direct and residual effect of FYM becomes pronounced on the system productivity during crop cycle due to improvement in soil health parameters. Application of organic amendments ensure long - term sustainability of soil fertility by improving levels of soil organic carbon, availability of nutrients and soil microbial activities (Malero *et al.* 2007 and Bodake and Rana 2009).

#### Nutrient concentration in maize and wheat

The concentration of various nutrients in maize and wheat significantly affected by K fertilization (Table 2 and

3). All the treatments with applied K were significantly superior over no K. In both maize and wheat application of 90 kg K/ha recorded highest concentration of nutrients in grains of maize and wheat.

The difference in various nutrient concentrations in maize and wheat was observed significant due to application of increased level of applied K. K uptake has synergistic effect on uptake of nitrogen, phosphorus, zinc and iron due to which all the treatments with K showed superiority over No K. Baque *et al.* (2006) reported that uptake of N, P and K was enhanced with increasing levels of K. Eldardiry *et al.* (2010) reported that application of different K levels results in differential nitrogen uptake by wheat grains and increasing K rates resulted in significant increase in P-uptake in straw and grains of wheat.

Ranade (2011) observed a direct synergistic relationship of potassium with Fe, whereas Gupta (1995) reported a positive interaction between Zn and potassium due to direct role of potassium in nutrient translocation resulting into increased concentration of Fe and Zn in grain. Chaudhary and Narwal (2005) reported that application of FYM helps in increasing availability of micronutrients in the soil. Potassium plays a vital role in translocation in the plants which increased the micronutrients uptake in plants and concentration of micronutrients in grain.

#### Regression analysis

K concentration in grain showed strong correlation with Zn and Fe concentration in grain (Fig 1a-d). Higher concentration of K in grain helped in increased concentration of Zn and Fe in grain. This implies that there is synergistic relationship exist between K, Zn and Fe uptake in grain. These results are in conformity with Ranade (2011) and Gupta (2005).

The study showed increased yield and system productivity due to integrated application of potassium.

Table 2 Effect of integrated potassium fertilization on macro nutrient concentration in grains of maize and wheat

Treatment	Maize						Wheat					
	N (%)		P (ppm)		K (ppm)		N (%)		P (ppm)		K (ppm)	
	2010	2011	2010	2011	2010	2011	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
K <sub>0</sub> (M) – K <sub>0</sub> (W)	1.56	1.54	0.32	0.33	0.41	0.43	1.43	1.41	0.27	0.26	0.44	0.42
MOP <sub>60</sub> (M) – K <sub>0</sub> (W)	1.68	1.73	0.34	0.34	0.47	0.55	1.49	1.47	0.28	0.27	0.46	0.43
MOP <sub>30</sub> +FYM <sub>30</sub> (M) – MOP <sub>60</sub> (W)	1.70	1.89	0.36	0.36	0.52	0.59	1.73	1.70	0.34	0.35	0.54	0.56
MOP <sub>60</sub> +FYM <sub>30</sub> (M) – K <sub>0</sub> (W)	1.77	1.96	0.37	0.38	0.57	0.63	1.59	1.56	0.29	0.28	0.47	0.45
MOP <sub>30</sub> +FYM <sub>30</sub> (M) – K <sub>0</sub> (W)	1.70	1.84	0.36	0.36	0.52	0.55	1.56	1.52	0.28	0.28	0.46	0.44
K <sub>0</sub> (M) –MOP <sub>60</sub> (W)	1.54	1.57	0.32	0.33	0.41	0.44	1.66	1.66	0.32	0.32	0.53	0.55
K <sub>0</sub> (M) – MOP <sub>30</sub> + FYM <sub>30</sub> (W)	1.54	1.58	0.32	0.33	0.41	0.44	1.77	1.75	0.35	0.34	0.56	0.58
MOP <sub>60</sub> (M) – MOP <sub>30</sub> + FYM <sub>30</sub> (W)	1.68	1.75	0.34	0.35	0.47	0.57	1.75	1.77	0.34	0.34	0.56	0.58
MOP <sub>60</sub> (M) – MOP <sub>60</sub> (W)	1.68	1.74	0.34	0.35	0.47	0.57	1.70	1.73	0.32	0.32	0.53	0.55
K <sub>0</sub> (M) – MOP <sub>60</sub> +FYM <sub>30</sub> (W)	1.54	1.59	0.32	0.33	0.41	0.45	1.82	1.78	0.35	0.35	0.57	0.59
LSD(P=0.05)	0.10	0.07	0.013	0.007	0.05	0.04	0.12	0.09	0.02	0.02	0.02	0.03

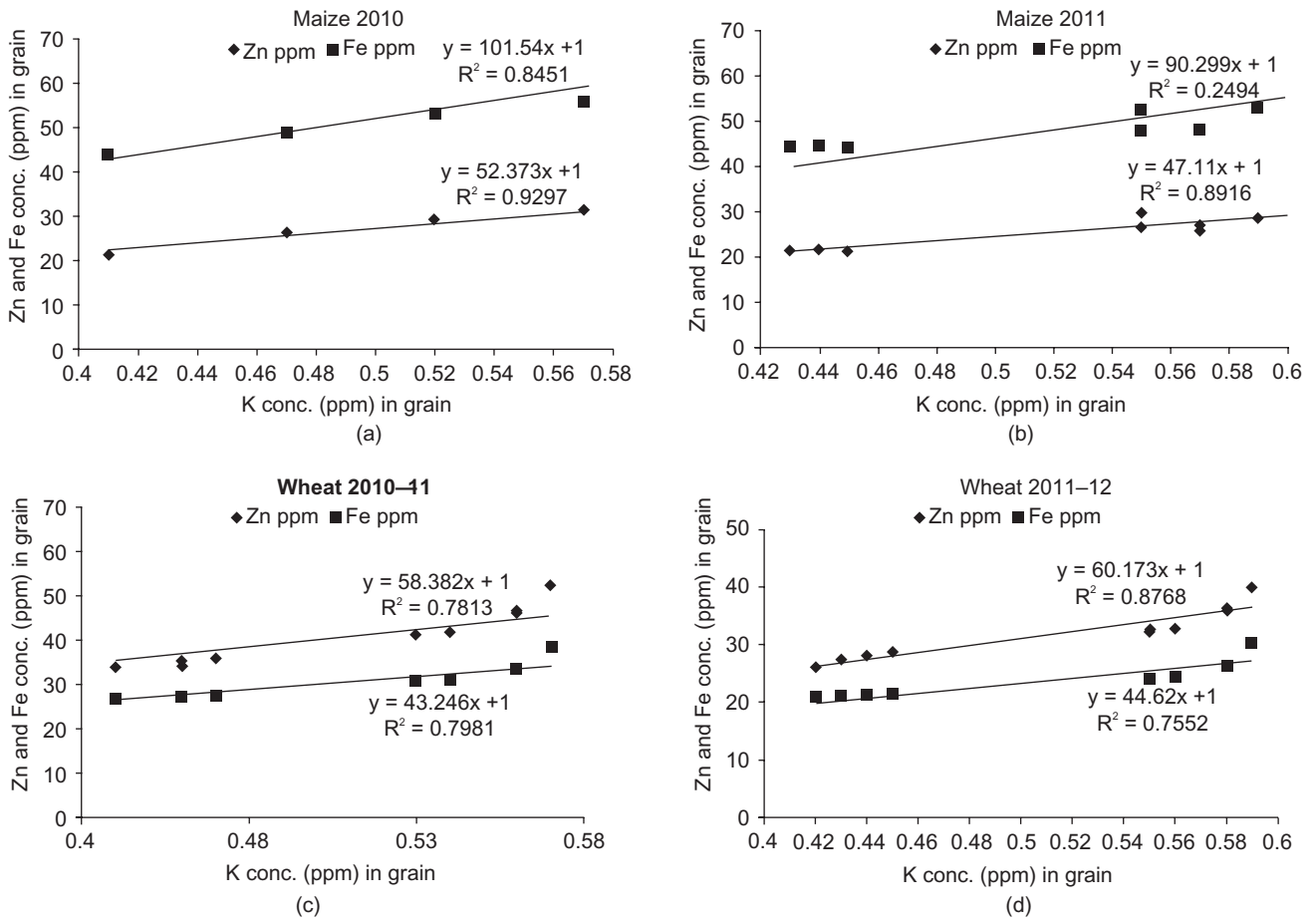


Fig 1 (a-d) a) Relationship between Zn and Fe conc. in grain with respect to K concentration in grain in maize 2010, b) Relationship between Zn and Fe conc. in grain with respect to K concentration in grain in maize 2011, c) Relationship between Zn and Fe conc. in grain with respect to K concentration in grain in wheat 2010-11 and d) Relationship between Zn and Fe conc. in grain with respect to K concentration in grain in wheat 2011-12.

The application of K results into better nutrient availability which improved concentration of nutrients in grain of maize and wheat. The result shows a synergistic effect of applied

K on uptake of N, P, K and micronutrient like Zn and Fe. Thus, K improved yield and quality of grains in maize and wheat.

Table 3 Effect of integrated potassium fertilization on Zn and Fe concentration (ppm) in grain of maize – wheat cropping system

Treatment	Maize				Wheat			
	Zn		Fe		Zn		Fe	
	2010	2011	2010	2011	2010–11	2011–12	2010–11	2011–12
K <sub>0</sub> (M) – K <sub>0</sub> (W)	21.2	21.4	44.5	44.9	25.5	26.1	20.2	21.0
MOP <sub>60</sub> (M)– K <sub>0</sub> (W)	26.2	26.5	48.5	48.0	25.8	27.5	20.3	21.2
MOP <sub>30</sub> +FYM <sub>30</sub> (M)–MOP <sub>60</sub> (W)	28.3	28.6	53.2	53.1	31.4	32.7	23.4	24.4
MOP <sub>60</sub> +FYM <sub>30</sub> (M) – K <sub>0</sub> (W)	31.4	31.8	56.2	56.6	27.1	28.7	20.7	21.5
MOP <sub>30</sub> +FYM <sub>30</sub> (M)– K <sub>0</sub> (W)	29.5	29.8	51.6	52.7	26.5	28.1	20.5	21.3
K <sub>0</sub> (M)–MOP <sub>60</sub> (W)	21.4	21.6	44.7	45.0	31.1	32.6	23.1	24.0
K <sub>0</sub> (M)– MOP <sub>30</sub> +FYM <sub>30</sub> (W)	21.4	21.6	44.3	44.7	35.2	36.4	25.1	26.1
MOP <sub>60</sub> (M)– MOP <sub>30</sub> + FYM <sub>30</sub> (W)	25.8	26.0	49.3	48.3	34.6	35.8	25.4	26.5
MOP <sub>60</sub> (M)– MOP <sub>60</sub> (W)	26.8	27.0	48.7	47.6	30.9	32.3	23.2	24.1
K <sub>0</sub> (M)–MOP <sub>60</sub> +FYM <sub>30</sub> (W)	21.2	21.4	43.9	44.3	39.5	39.8	29.1	30.3
LSD(P=0.05)	3.97	3.9	2.4	3.0	2.7	2.8	0.8	0.8

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