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# Bio fortification of crop residues for animal feeding in maize-wheat cropping system through integrated potassium management

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**Abstract**
A field experiment was conducted during the rainy and winter seasons of 2010-11 and 2011-12 at Indian Agriculture Research Institute, New Delhi to find out the effect of integrated potassium fertilization on yield and quality of dry fodder of maize (*Zea mays* L.) and wheat (*Triticum aestvum* L.) crops grown in sequence. 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 crop residue yield in maize. The application of 60 kg K through muriate of potash + 30 kg K through farmyard manure resulted into highest crop residue yields (6.53 and 7.03 t $ha^{-1}$) in maize. In wheat, there was no significant difference in crop residue yields in different K treatments. In both the crops treatment applied with 60 kg K through muriate of potash + 30 kg K through farmyard manure resulted in enriched crop residues of maize and wheat crop with higher concentration of macro and micro nutrients. A strong correlation was recorded between K concentration in maize and wheat crop residues with N, P, K, Zn and Fe concentrations.

**Keywords:** Crop residue, Cropping system, Maize, Nutrient concentration, Potassium levels, Wheat

## Introduction

Agriculture and animal husbandry in India are integral part of rural living. The three major sources of fodder supply to animals are crop residues, cultivated fodder and fodder from common property resources like forests, permanent pastures and grazing lands. At present, the country faces a net deficit of 35.6% green fodder, 10.95% dry crop residues and 44% concentrate feed ingredients (Anonymous, 2013). Poor quality crop residues are still major source of livestock feed, leaving animals underno-urished, which increases their susceptibility to diseases, lowers reproduction efficiency and ultimately affects milk and meat production for human beings. This is a matter of great concern for a country like India. In animal feed supply, maize and wheat crops have a major role and provide a large amount of dry fodder from their residues. But these crop residues are generally poor in quality, specifically in macro and micronutrients. Survey on micronutrient status in green and dry fodder to support animal health in Vadodara district of Gujarat indicated that though most of the soils are adequate in available Fe, Mn and Cu to support crop yields, but they need Zn fertilization to get good yields, and crop residues were found low in Fe, Zn and Cu (Narwal *et al*, 2013). Similar studies intended to assess the effect of micronutrient status in soil-plant-animal continuum, revealed that soil of Dahima village of Hisar, Haryana, was found deficient in Fe, P and Zn and the fodders grown on these soils did not meet the normal mineral requirement of animals (Narwal *et al.*, 2013).

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). The removal of K by plants has been observed comparatively higher than the removal of nitrogen but the consumption ratio of N: $K_2O$ is 7:1 (Maene, 2001). Unlike N, application of K is often inadequate when compared to the amount required by the crops particularly in India. As a consequence, 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. 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, many soils with very low K fertility status started limiting the responses to application of N and P (Singh and Swarup, 2000). There is a growing evidence of increasing deficiency of potassium (K) as a result of imbalanced use of N and P. Potassium is very crucial for its interaction both antagonistic and synergistic with essential macro and micro nutrients (Dibb and Thomson, 1985).

From the above facts it is clear that because of heavy withdrawal of nutrients from soil under multiple cropping systems with high yielding and fertilizer responsive varieties, the potassium status of soil is declining rapidly which may lead to decline in crop residue quality. Therefore, it is necessary to keep a close watch on such depletion of soil K through regular monitoring to ensure that K does not become a limiting factor in optimizing crop production. Keeping in view the above facts, the present investigation was conducted to study the effect of integrated K management on the crop residue quality in maize - wheat cropping system.

**Materials and Methods**

The field experiments were conducted during the 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 mean sea level. The experiment on maize - wheat cropping system was carried out using randomized block design with three replications and ten treatment combination 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% and available N 173.2 kg $ha^{-1}$ (by alkaline permanganate method). P (13.8 kg $ha^{-1}$) and K (261 kg $ha^{-1}$) was estimated by Flame photometer. Recommended dose of 150 kg N $ha^{-1}$ and 26 kg P $ha^{-1}$ were applied to maize through urea and DAP, respectively. In maize the full dose of P, K and 50 kg N $ha^{-1}$ were given as basal and remaining 100 kg N $ha^{-1}$ was given as 50 kg N $ha^{-1}$ each at 30 days after sowing (DAS) in 1st split and 50 kg N $ha^{-1}$ was given in 2nd 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 $ha^{-1}$ were given as basal and remaining 60 kg N $ha^{-1}$ was given as 30 kg N $ha^{-1}$ each at 30 days after sowing (DAS) in 1st split and 30 kg N $ha^{-1}$ in 2nd split at 60 DAS. Similarly, potassium was applied as per treatments: No K to maize and wheat -– $K_0$ (M) – $K_0$ (W), 60 kg K $ha^{-1}$ through MOP in maize and no K in wheat – $MOP_{60}$ (M) – $K_0$(W), 30 kg K through MOP and 30 kg K through FYM in maize and 60 kg K through MOP in wheat – $MOP_{30}$ + $FYM_{30}$(M) – $MOP_{60}$ (W), 60 kg K through MOP and 30 kg K through FYM in maize and no K in wheat – $MOP_{60}$ + $FYM_{30}$ (M) – $K_0$ (W), 30 kg K through MOP and 30 kg K through FYM in maize and no K in wheat – $MOP_{30}$ + $FYM_{30}$ (M) – $K_0$ (W), no K in maize and 60 kg K through MOP in wheat – $K_0$ (M) –$MOP_{60}$ (W), no K in maize and 30 kg K through MOP and 30 kg K through FYM in wheat – $K_0$ (M)– $MOP_{30}$ + $FYM_{30}$ (W), 60 kg K through MOP in maize and 30 kg K through MOP and 30 kg K through FYM in wheat – $MOP_{60}$ (M) – $MOP_{30}$ + $FYM_{30}$ (W), 60 kg K through MOP in maize and 60 kg K through MOP in wheat – $MOP_{60}$ (M)– $MOP_{60}$ (W), no K in maize and 60 kg K through MOP and 30 kg K through FYM in wheat – $K_0$ (M) –$MOP_{60}$ + $FYM_{30}$ (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 x 20 cm for maize and 22.5 cm row spacing for wheat. The seed rate used for maize was 20 kg $ha^{-1}$ and wheat 100 kg $ha^{-1}$.

At maturity, plants of maize and wheat were harvested manually from an area of 4.8 and 4.5 $m^{-2}$ respectively from the centre of each plot. Dry weights of stems and grains were determined after separation. The crop residue yield per hectare was calculated based on the dried plant samples after separation of grain. After grinding, the dried material was used to analyze for nitrogen content and concentration of macro and micro nutrients by standard procedure (Prasad *et al.,* 2006). Protein content in maize stover as well as wheat straw was calculated by multiplying nitrogen per cent by the factor 6.25. The standard error of mean (SEm), least significant difference (LSD) at 0.05 probability and coefficient of variation (CV) were worked out for each parameter by using Analysis of Variance (ANOVA) technique for randomized block design in both maize and wheat crop as per standard procedure (Gomez and

Gomez, 1984).

## Results and Discussion

***Crop residue yields of maize and wheat:*** Crop residue yields of maize differed significantly due to K application (Table 1). The result indicated that all the treatments with K showed significant superiority over control with no K application for crop residue yield. The treatment $MOP_{60}$+$FYM_{30}$ (M) – $K_0$ (W) recorded highest crop residue yields (6.53 t /ha and 7.03 t/ha) over remaining treatments during rainy season 2010 and 2011, respectively. The treatment applied with 60 kg K through MOP and 30 kg K through FYM was closely followed by treatment applied with 30 kg K through MOP and 30 kg K through FYM and these were at par with each other and significantly superior over remaining treatments. No significant difference was observed in crop residue yields from wheat in both the years of experimentation. However, application of $K_0$ (M)–$MOP_{60}$ +$FYM_{30}$ (W) yielded highest crop residues.

The improvement in yield was due to applied potassium as it was vital to many plant processes including photosynthesis, translocation of photosynthates, protein synthesis, activation of plant enzymes etc (IPNI, 1998). Farm yard manure supplied nitrogen, phosphorus and potassium in available forms to the plants through biological decomposition along with micronutrients which resulted into higher yields in maize. But similar effect was not observed in case of wheat. 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. Treatments applied with 60 kg K $ha^{-1}$ over no potassium (control) showed more yield due to increased amount of K (Mumtaz *et al.*, 1999; Tabatabaii *et al.*, 2011). Zhang *et al.* (2011) found that inorganic NPK fertilization significantly increased grain yields of wheat (21%) and maize (16 - 72%) compared to inorganic nitrogen and phosphorus fertilization. Similarly, positive results were reported by Mehdi *et al.* (2001), Saifullah *et al.* (2002), Polara *et al.* (2010) and Rehman *et al.* (2008) for wheat crop.

***Crude protein content and yield:*** The difference in protein content and protein yield in maize and wheat was observed significant due to application of increased level of potassium. In maize crop residue, protein content and protein yield was significantly affected by K fertilization (Table 1). All the treatments applied with potassium were significantly superior over $K_0$. Treatment applied with 60 kg K through MOP with 30 kg K through FYM recored highest protein content (2.63 and 2.63 %) and protein

**Table 1.** Effect of integrated potassium fertilization on crop residue yield (t $ha^{-1}$), crude protein content (%) and protein yield (t $ha^{-1}$) of maize and wheat in maize-wheat cropping system

| Treatment | Maize | | | | | | Wheat | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Crop residue | | Crude protein | | Protein yield | | Crop residue | | Crude protein | | Protein yield | |
| | 2010 | 2011 | 2010 | 2011 | 2010 | 2011 | 2010–11 | 2011 – 12 | 2010–11 | 2011 – 12 | 2010–11 | 2011 – 12 |
| $K_0$(M) – $K_0$(W) | 4.48 | 5.26 | 1.31 | 1.31 | 0.06 | 0.07 | 7.30 | 7.59 | 2.04 | 1.98 | 0.15 | 0.15 |
| $MOP_{60}$(M)-$K_0$(W) | 5.07 | 6.33 | 2.19 | 2.02 | 0.11 | 0.13 | 7.75 | 8.06 | 2.33 | 2.19 | 0.18 | 0.18 |
| $MOP_{30}$+$FYM_{30}$(M)–$MOP_{60}$(W) | 5.90 | 6.75 | 2.19 | 2.29 | 0.13 | 0.15 | 8.13 | 8.53 | 2.33 | 2.33 | 0.19 | 0.20 |
| $MOP_{60}$+$FYM_{30}$(M) –$K_0$(W) | 6.53 | 7.03 | 2.63 | 2.63 | 0.17 | 0.18 | 7.78 | 8.09 | 2.19 | 2.33 | 0.17 | 0.19 |
| $MOP_{30}$+$FYM_{30}$(M) –$K_0$(W) | 5.83 | 6.62 | 2.04 | 2.13 | 0.12 | 0.14 | 7.76 | 8.07 | 2.19 | 2.19 | 0.17 | 0.18 |
| $K_0$(M)–$MOP_{60}$(W) | 4.54 | 5.64 | 1.46 | 1.44 | 0.07 | 0.08 | 7.86 | 8.17 | 2.19 | 2.19 | 0.17 | 0.18 |
| $K_0$(M) –$MOP_{30}$+$FYM_{30}$(W) | 4.39 | 5.72 | 1.46 | 1.48 | 0.06 | 0.08 | 8.18 | 8.66 | 2.48 | 2.48 | 0.20 | 0.21 |
| $MOP_{60}$(M)–$MOP_{30}$+$FYM_{30}$ (W) | 5.14 | 6.53 | 2.19 | 2.04 | 0.11 | 0.13 | 8.14 | 8.77 | 2.48 | 2.54 | 0.20 | 0.22 |
| $MOP_{60}$ (M) –$MOP_{60}$ (W) | 5.21 | 6.43 | 2.04 | 2.04 | 0.11 | 0.13 | 7.93 | 8.24 | 2.33 | 2.33 | 0.19 | 0.19 |
| $K_0$ (M)–$MOP_{60}$ +$FYM_{30}$(W) | 4.47 | 5.83 | 1.31 | 1.54 | 0.06 | 0.09 | 8.20 | 8.98 | 2.63 | 2.56 | 0.22 | 0.23 |
| LSD($P=0.05$) | 0.44 | 0.71 | 0.25 | 0.26 | 0.02 | 0.03 | N.S | N.S | N.S | NS | NS | NS |

yield (0.17 t $ha^{-1}$ and 0.18 t $ha^{-1}$) which was significantly superior over treatment applied with no potassium whereas in wheat crop residue, crude protein content and protein yield was found non-significant. Treatment $K_0$(M)–$MOP_{60}$ +$FYM_{30}$(W) recorded highest protein content (2.63 and 2.56 %) and protein yield (0.22 t $ha^{-1}$ and 0.23 t $ha^{-1}$) in wheat. Potassium played a vital role in translocation processes in the plants which increased the macro and micronutrients uptake in plant body which resulted in increased concentration of these nutrients in the crop residue. Potassium had synergistic effect on uptake of nitrogen and other nutrients due to which all the treatments applied with potassium showed higher concentration of these nutrients in the plants over control. Baque *et al.* (2006) reported that uptake of N, P and K was enhanced with increasing levels of K. Similar results were also reported by Kalpana and Krishnaranjan (2002), Alias *et al.* (2009) and Kumar and Shiva Dhar (2013).

***Nutrient concentration in crop residue:*** In maize crop residue, concentration of macronutrients like N, P and K increased significantly by K fertilization (Table 2). All the treatments applied with potassium were found significantly superior over control (without K application). Treatment applied with 60 kg K through MOP and 30 kg K through FYM recorded highest concentration of N (0.42% and 0.41%), P (0.074% and 0.082%) and K (1.83% and 1.91%). Similarly, application of K also increased concentration of micronutrients like Zn and Fe in maize stover (Table 3). Application of 60 kg K through MOP and 30 kg K through FYM recorded highest concentration of Zn (122.1 ppm and 124.6 ppm) and Fe (140.5 ppm and 168.6 ppm) in the stover of maize.

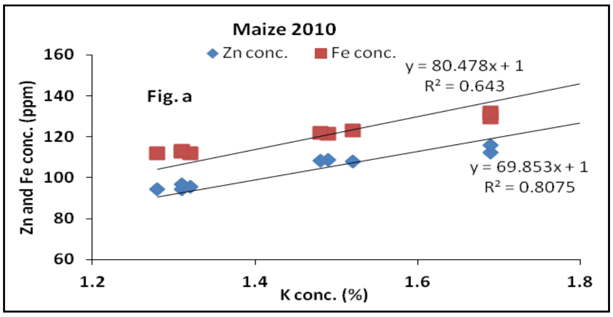
In wheat straw, concentration of P, K, Zn and Fe was significantly affected by K fertilization (Table 2 and 3). Treatments with applied potassium were significantly superior with respect to above nutrients except N. No significant effect of potassium application was recorded on the concentration of N and protein content in wheat crop residue. Application of 60 kg K through MOP and 30 kg K through FYM recorded highest concentration of N (0.42% during both the years), P (0.063% and 0.065%), K (1.63% and 1.65%), Zn (60.7 ppm and 68.6 ppm) and Fe (313.5 ppm and 319.8 ppm). The difference in concentration of these nutrients varied significantly in maize and wheat due to application of increased level of potassium. Enhanced uptake of N, P and K with increasing levels of K was also reported earlier (Kumar and Shiva Dhar 2013; Meena and Meena, 2012; Baque *et al.*, 2006; Kalpana and Krishnaranjan, 2002; Alias *et*

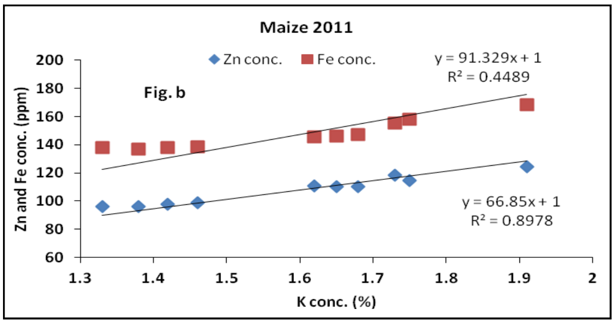
**Table 2.** Effect of integrated potassium fertilization on macro nutrient concentration (%) in straw of maize and wheat in maize - wheat cropping system

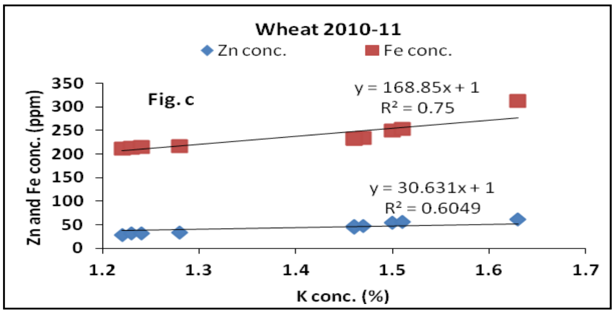
| Treatment | Maize | | | | | | Wheat | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | | P | | K | | N | | P | | K | |
| | 2010 | 2011 | 2010 | 2011 | 2010 | 2011 | 2010–11 | 2011 - 12 | 2010–11 | 2011 - 12 | 2010–11 | 2011 – 12 |
| $K_0$(M) – $K_0$(W) | 0.21 | 0.21 | 0.055 | 0.053 | 1.31 | 1.33 | 0.33 | 0.32 | 0.055 | 0.054 | 1.22 | 1.21 |
| $MOP_{60}$ (M) – $K_0$(W) | 0.35 | 0.32 | 0.063 | 0.065 | 1.49 | 1.62 | 0.37 | 0.35 | 0.057 | 0.056 | 1.23 | 1.24 |
| $MOP_{30}$+$FYM_{30}$(M)–$MOP_{60}$(W) | 0.35 | 0.37 | 0.065 | 0.075 | 1.69 | 1.75 | 0.37 | 0.37 | 0.062 | 0.063 | 1.47 | 1.48 |
| $MOP_{60}$+$FYM_{30}$(M) – $K_0$(W) | 0.42 | 0.42 | 0.074 | 0.082 | 1.83 | 1.91 | 0.35 | 0.37 | 0.058 | 0.057 | 1.28 | 1.28 |
| $MOP_{30}$+$FYM_{30}$(M) – $K_0$(W) | 0.33 | 0.34 | 0.066 | 0.074 | 1.69 | 1.73 | 0.35 | 0.35 | 0.057 | 0.056 | 1.24 | 1.25 |
| $K_0$(M) –$MOP_{60}$ (W) | 0.23 | 0.23 | 0.054 | 0.055 | 1.28 | 1.38 | 0.35 | 0.35 | 0.061 | 0.063 | 1.46 | 1.45 |
| $K_0$(M) – $MOP_{30}$+ $FYM_{30}$(W) | 0.23 | 0.24 | 0.054 | 0.056 | 1.32 | 1.42 | 0.40 | 0.40 | 0.062 | 0.064 | 1.50 | 1.51 |
| $MOP_{60}$ (M) – $MOP_{30}$ +$FYM_{30}$(W) | 0.35 | 0.33 | 0.063 | 0.067 | 1.48 | 1.68 | 0.40 | 0.41 | 0.064 | 0.064 | 1.51 | 1.50 |
| $MOP_{60}$ (M) – $MOP_{60}$ (W) | 0.33 | 0.33 | 0.063 | 0.066 | 1.52 | 1.65 | 0.37 | 0.37 | 0.061 | 0.063 | 1.46 | 1.46 |
| $K_0$(M) – $MOP_{60}$ +$FYM_{30}$ (W) | 0.21 | 0.25 | 0.054 | 0.058 | 1.31 | 1.46 | 0.42 | 0.41 | 0.063 | 0.065 | 1.63 | 1.64 |
| LSD(P=0.05) | 0.04 | 0.04 | 0.004 | 0.006 | 0.11 | 0.14 | NS | NS | 0.002 | 0.005 | 0.06 | 0.08 |

*al.,* 2009).

***Pearson's correlation matrix between K uptake and Zn and Fe concentration in crop residues:*** Increment in K levels in wheat and maize increased the K concentration in crop residue. K concentration showed strong correlation with Zn and Fe concentration in crop residue (Fig a-d). Application of K showed synergistic effect on K concentration of crop residues which helped to improve the concentration of Zn and Fe in crop residues. This implies that there is synergistic relationship exist between K, Zn and Fe uptake in crop residue. Thus, quality of crop residues was enhanced due to K application. These results were in conformity with Ranade (2011) and Gupta (1995).



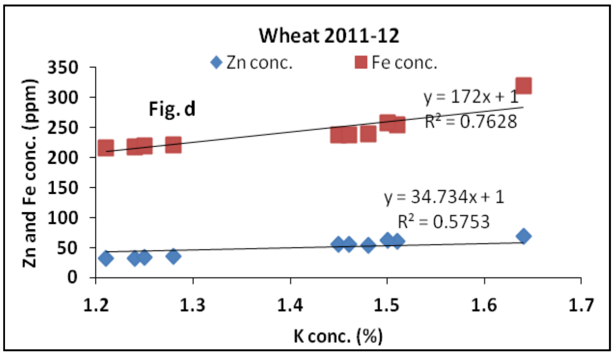




**Fig (a-d)** a) Relationship between Zn and Fe conc. in maize crop residue with respect to K concentration in 2010, b) Relationship between Zn and Fe conc. in maize crop residue with respect to K concentration in 2011, c) Relationship between Zn and Fe conc. in wheat crop residue with respect to K concentration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

## Conclusion

Based on the two year study on effect of integrated K fertilization, it was concluded that application of potassium irrespective of sources improved the crop residue yield of maize only. However, the application of potassium enhanced quality of maize and wheat crop residues through improvement of protein content as well as N, P, K, Zn and Fe concentrations.

**Table 3.** Effect of integrated potassium fertilization on Zn and Fe concentration (ppm) in straw of maize and wheat in maize – wheat cropping system and protein productivity

| Treatment | Maize | | | | Wheat | | | |
|---|---|---|---|---|---|---|---|---|
| | Zn | | Fe | | Zn | | Fe | |
| | 2010 | 2011 | 2010 | 2011 | 2010–11 | 2011 - 12 | 2010–11 | 2011 - 12 |
| $K_0$ (M) – $K_0$ (W) | 94.4 | 96.3 | 112.5 | 137.7 | 28.7 | 31.8 | 211.7 | 216.0 |
| $MOP_{60}$ (M)– $K_0$(W) | 108.8 | 110.9 | 121.3 | 145.5 | 31.6 | 32.4 | 213.5 | 217.8 |
| $MOP_{30}$+$FYM_{30}$(M)–$MOP_{60}$(W) | 112.4 | 114.8 | 129.6 | 158.3 | 47.7 | 53.3 | 234.9 | 239.6 |
| $MOP_{60}$+$FYM_{30}$(M) – $K_0$(W) | 122.1 | 124.6 | 140.5 | 168.6 | 32.5 | 35.2 | 215.8 | 220.1 |
| $MOP_{30}$+$FYM_{30}$(M)– $K_0$(W) | 116.0 | 118.3 | 131.9 | 155.5 | 31.2 | 33.9 | 214.2 | 218.5 |
| $K_0$(M)–$MOP_{60}$ (W) | 94.2 | 96.1 | 111.9 | 137.1 | 44.1 | 55.2 | 232.6 | 237.2 |
| $K_0$(M)– $MOP_{30}$+$FYM_{30}$(W) | 95.7 | 97.6 | 112.0 | 137.7 | 53.5 | 61.0 | 249.7 | 254.7 |
| $MOP_{60}$ (M)– $MOP_{30}$ + $FYM_{30}$ (W) | 108.2 | 110.3 | 121.7 | 147.4 | 55.2 | 62.3 | 252.7 | 257.7 |
| $MOP_{60}$ (M)– $MOP_{60}$ (W) | 108.1 | 110.2 | 122.9 | 146.1 | 47.2 | 55.0 | 233.2 | 237.8 |
| $K_0$ (M)–$MOP_{60}$ +$FYM_{30}$ (W) | 96.7 | 98.6 | 113.1 | 138.5 | 60.7 | 68.6 | 313.5 | 319.8 |
| LSD(P=0.05) | 10.4 | 10.6 | 6.8 | 5.2 | 6.3 | 4.6 | 8.3 | 4.8 |

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