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# PHENOLOGY AND YIELD OF COARSE AND FINE RICE UNDER VARYING LEVELS OF ZINC AND FARMYARD MANURE

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**Abstract**

In order to investigate the effect of Zn and FYM levels on phenology and yield of coarse and fine rice cultivars, field experiments were conducted at Agriculture Research Institute Swat, Khyber Pakhtunkhwa, Pakistan during summer 2013 and 2014. The experiments were laid out in RCB design with split plot arrangements having three replications. The experiment consisted of four levels of Zn (0, 6, 12 and 18 kg $ha^{-1}$) and two levels of FYM (0 and 15 t $ha^{-1}$) applied to two rice cultivars, coarse rice cultivar (Fakhr-e-Malakand) and fine rice (Basmati-385). Application of FYM at the rate 15 t $ha^{-1}$ produced taller plants, hastened heading, physiological maturity and shortened grain filling duration by 4, 2 and 6 days, respectively over control whereas biological and grain yield increased by 51% and 48%, over control plots. Likewise, Zn level of 18 kg $ha^{-1}$ increased plant height by 4.6%, hastened heading by 3 days and extended grain filling duration by 4 days while biological yield and grain yield increased by 11.51 % and 22 %, respectively over control. Fine rice cultivar Basmati-385 had taller plants, delayed heading, physiological maturity and 19.31 % and 17.91% lower biological and grain yields, as compared to coarse rice cultivar Fakhr-e-Malakand. It is concluded that the application Zn and FYM either alone or in combination can substantially improve rice productivity.

**Key words:** Rice, Cultivars, Zinc, FYM, Biological yield, Grain yield.

## Introduction

Rice (*Oryza sativa* L.) is one of the most important cereal crops in human nutrition, consumed by about 75% of the global population. Among the cereals, rice and wheat share equal importance as leading food sources for humankind. Rice is a staple food for nearly one-half of the world’s population and provides 60% of the food intake in Southeast Asia (Anjum *et al*., 2007). Rice including both fine and course varieties, is planted on about an area of over 2.57 million ha (10% of the total cropped area) and accounts for 17% of the total cereals produced annually in the country (Ali *et al*., 2014). According to Pakistan Economic Survey (2014-15) rice crop contributed by 3.2% in the value added agriculture products and 0.7% to the total country GDP. Export of fine aromatic rice earned a foreign exchange of 1.53 USD billion during 2014-15. The crop was cultivated on an area of 2891 (000) hectares with 3.6% increase in area of cultivation over the last years (2013-14). Pakistan ranks $11^{th}$ in rice production among the rice producing countries of the world (Wasim, 2002).

Rice productivity is reduced by a number of problems, the major causes are the limited availability of certified and quality seed, low plant population, Zn deficiency, imbalanced use of fertilizers, soil salinity, shortage of irrigation water, diseases, insects pests infestation, post-harvest losses and socio-economic constraints (Akhtar *et al*., 2007). Micro-nutrients especially Zn plays an important role in plant nutrition and certain metabolic processes such as enzymatic reactions (Malik *et al*., 2008). Zinc plays a key role in structural constitution or regulatory co-factor of a wide range of different enzymes and proteins in many important biochemical pathways such as carbohydrate metabolism, both in photosynthesis and in the conversion of sugars to starch, protein metabolism, auxin (growth regulator) metabolism, pollen formation, the maintenance of the integrity of biological membrane and resistance to infection by certain pathogens (Alloway, 2008). Zn enriched manure has a significant residual effect on the yield and Zn uptake by many crops. According to Latha *et al*., (2002) irrespective of the manure sources, the seed and stalk yield of sunflower was significantly influenced by the residual effect of zinc enriched manure application. The seed yield of sunflower significantly increased by 15 per cent over control for residual effect of zinc sulphate application at 25 kg $ha^{-1}$ while for that of manures, yield increase was upto 12 per cent over control. Among the manures poultry manure was superior and recorded the highest uptake of Zn by sunflower seed for the residual effect followed by biogas slurry. Zn deficiency is one of the major problems in rice productivity and nutritive quality due to either Zn deficiency or problems associated with Zn uptake, therefore using Zn in combination with FYM or other organic manures will mitigate the problem and contribute to increase in rice productivity and enhancing its nutritional value (Jadhav *et al*., 2003). Zn deficiency is widespread among plants in calcareous soils of high pH resulting mainly from the adsorption of zinc to clay or Ca-$CO_3$ rather than from the formation of sparingly soluble Zn $(OH)_2$ or $ZnCO_3$ (Trehan & Sekhon, 1977). Keeping in view the importance of rice in human nutrition, food security and gaps in production and quality, the research experiments were designed with the objectives to investigate the effects different nutrient regimes (Zn and Zn enriched FYM) on productivity, growth and nutritional characteristics of coarse (Fakhr-e-Malakand) and fine rice (Basmati-385).

## Materials and Methods

The research experiments were carried out at ARI (Agriculture Research Institute), Mingora Swat, KP, Pakistan. The institute is located at 34° and 36° North latitude and 72° and 73° East longitude and at an altitude of 975 meters above sea level. Soil analysis and other qualitative tests were conducted at the research laboratory of the institute (Tables 1 & 2).

The average of the two experimental year's weather data for rainfall, relative humidity and temperature of the experimental site were recorded at ARI-North Swat, are presented in Fig. 1.

**Table 1. Physicochemical properties of the soil.**

| Characteristics | Values |
|---|---|
| Clay (%) | 13.6 |
| Silt (%) | 54 |
| Sand (%) | 32 |
| Texture class | Silt Loam |
| EC (dS m-1 ) | 0.1 |
| Soil pH | 6.2 |
| Organic matter (%) | 1.24 |
| Lime (%) | 4 |
| Nitrogen (%) | 0.035 |
| Phosphorous (mg $kg^{-1}$) | 5 |
| Potash (mg $kg^{-1}$) | 82 |
| Zn (mg $kg^{-1}$) | 2.29 |

Well-decomposed FYM was analysed for major and micronutrients at the ARI soil laboratory.

**Table 2. Analysis of FYM for macro and micronutrients.**

| Nutrient | Content (%) |
|---|---|
| Nitrogen | 0.42 |
| Phosphorous | 0.31 |
| Potassium | 0.38 |
| Sodium | 0.07 |
| Sulphur | 0.03 |
| Zinc | 0.003 |
| Copper | 0.0004 |
| Manganese | 0.005 |
| Iron | 0.52 |

**Experimental design:** The study was carried out in randomized complete block design with split plot arrangement replicated thrice. Nursery sowing and transplantation were carried out for both the years of the experiments on 20th May, 20th June, 2013 and 22nd May, 25th June, 2014, respectively. The crop was harvested on 1st to 5th November in 2013 and 2nd to 8th November, in 2014.

Rice grains were analysed for crude fibre using the AoAC, (2000) analysis procedures while grain protein were determined through *Kjeldahl* digestion method. Dry ashing method was used for the analysis of Zn in grain and plant tissues. Soil pH, electrical conductivity and soil textural classes were recorded by pH, EC meter and hydrometer respectively. Soil of the experimental site was analysed for organic matter using Walkley-Black Method (1934). AB-DTPA method was used for the analysis of soil P and K. The weather data of the site was recorded by Automated Weather station CR 1000 at ARI.

The experimental treatments consisted of four levels of Zn (0, 6, 12 and 18 kg $ha^{-1}$), two cultivars (coarse cultivar called Fakhre Malakand, fine cultivar Basmatic-385) and two levels of FYM (0 and 15 t $ha^{-1}$). Certified seed of rice cultivars was used for the experiments. Planting geometry consisted of 150 hills in a 6 $m^2$ plot (3 m long and 2 m wide) with row and plant to plant distance of 20 cm. Total numbers of hills and rows $plot^{-1}$ were 15 and 10 with planting density of 150 plants $plot^{-1}$. Three seedlings were used $hill^{-1}$. Recommended crop production and protection measures such as basal dose application of N,P,K, soil sample collection, analysis for physical and chemical properties and analysis of FYM, were carried out. Ammonium Sulphate $(NH4)_2SO_4$ (21%N) and Zinc Sulphate ($ZnSO_4$) (36% Zn) were used for N and Zn sources, respectively.

**Data collection method:** Data were recorded on plant height, days to 50% heading, grain filling duration, days to maturity, biological yield, and grain yield.

1. Plant height was calculated at full maturity of the plant by taking actual measurement (cm) from soil surface to the tip of the panicle with the help of measuring rod. Ten plants were randomly selected $plot^{-1}$ and average plant height was calculated.
2. The data on days to heading initiation was recorded through regular observation of the plots by recording the days from transplantation to 50% heading on the plants sown in the three central rows.
3. Data on the days to maturity were recorded from the date of transplantation to the stage of maturity through regular field observation.
4. The data on the grain filling duration was recorded from the date of panicle grain appearance on the spikelet upto the date when the grains attained physiological maturity i.e. when no more grain filling was taking place.
5. Biological yield was recorded by harvesting three central rows from each plot, sun dried and weighed. Biological yield was calculated by using the following formula:

$$\text{Biological yield kg ha}^{-1} = \frac{\text{Biological yield of three rows}}{\text{Row-Row (m) x 3 x Row length (m)}} \times 10{,}000$$

6. The grain yield of each plot was recorded by harvesting and threshing three central rows. The grains collected from the rows were converted to grain yield kg $ha^{-1}$ by using the following formula:

$$\text{Grain yield kg ha}^{-1} = \frac{\text{Grain yield of three rows}}{\text{Row-Row (m) x 3 x Row length (m)}} \times 10{,}000$$

**Table 3. Plant height (cm), days to 50% heading, grain filling duration and days to maturity of rice cultivars as affected by different FYM and Zn levels during summer 2013 and 2014.**

| FYM (t $ha^{-1}$) | Plant height (cm) | Days to 50% heading | Grain filling duration (days) | Days to maturity |
|---|---|---|---|---|
| 0 | 122.7 b | 73 a | 34 a | 106.6 b |
| 15 | 125.0 a | 69 b | 40 b | 108.5 a |
| **Significance level** | * | ** | ** | ** |
| **Rice cultivars** | | | | |
| Fakhr-e- Malakand | 110.6 b | 65 b | 36 | 101.4 b |
| Basmati-385 | 137.1 a | 77 a | 37 | 113.7 a |
| **Significance level** | ** | ** | ns | ** |
| **Zn levels (kg $ha^{-1}$)** | | | | |
| 0 | 119.7 b | 72 a | 35 c | 107.7 ab |
| 6 | 125.9 a | 72 a | 35 c | 106.7 b |
| 12 | 124.6 a | 70 b | 38 b | 107.6 ab |
| 18 | 125.3 a | 69 c | 39 a | 108.2 a |
| **$LSD_{0.05}$** | **2.7** | 0.6 | 0.8 | 1.04 |
| **Interactions** | | | | |
| Zn x C | NS | NS | NS | NS |
| FYM x C | ** | ** | ** | NS |
| FYM x Zn | NS | ** | ** | * |
| FYM x Zn x C | NS | NS | * | * |

"*" and "**" = Significant at 5 and 1% level of probability. "NS"= Non-significant

## Results

**Plants height (cm):** Plant height was significantly influenced by the main effects of FYM, varieties and Zn rates (Table 3). The interaction of FYM x C was significant but the remaining interactions were not significant. Application of FYM increased plant height from 122.7 to 125.0 cm; fine rice Basmati-385 produced taller plants as compared to coarse rice Fakhr-e-Malakand. Plant height increased from 119.7 cm to 125.3 cm with increasing Zn levels upto the maximum Zn rate of 18 kg $ha^{-1}$. The FYM x C interaction showed that plant height increased with FYM application and the increase was 5% in coarse rice cultivar Fakhr-e-Malakand and 1% in fine rice cultivar Basmati-385 as compared to control (Fig. 2).

**Days to 50% heading:** Days to 50% heading was significantly influenced by the main effects of Zn and FYM (Table 3). The FYM x C and FYM x Zn interactions were significant but the remaining interactions were not significant. Application of FYM at the rate of 15 t $ha^{-1}$ decreased days to heading from 73 to 69 days compared to controlled plots. Coarse rice cultivar Fakhr-e-Malakand took 65 days in reaching 50% heading as compared to 77 days in fine rice cultivar Basmati-385. Days to heading decreased from 72 days to 69 days with increasing Zn levels upto the maximum Zn rate of 18 kg $ha^{-1}$.

The interaction of FYM x C reflected that days to 50% heading decreased with application of FYM at the rate of 15 t $ha^{-1}$ and the decrease was 13% in coarse rice cultivar Fakhr-e-Malakand whereas fine rice Basmati-385 did not show any significant response to FYM for days to 50% heading (Fig. 3). The interaction of FYM x Zn revealed that days to 50 % heading decreased with increasing Zn levels upto maximum of Zn rate of 18 kg $ha^{-1}$, the decrease was 6% at 0 t $ha^{-1}$ FYM and 3% at 15 t FYM $ha^{-1}$ (Fig. 4).

**Grain filling duration (days):** Grain filling duration (days) was influenced by the main effects of FYM, cultivars and Zn rate (Table 3). The interactions of FYM x C, FYM x Zn and FYM x Zn x C were significant while the remaining interactions were not significant. Application of FYM at the rate of 15 t $ha^{-1}$ increased grain-filling duration from 34 to 40 days as compared to 0 t FYM $ha^{-1}$. Grain filling duration increased from 35 to 39 days with increasing Zn levels upto the maximum of 18 kg Zn $ha^{-1}$.

The interaction of FYM x C revealed that grain filling increased with application of FYM at the rate of 15 t $ha^{-1}$ as compared to 0 t FYM $ha^{-1}$ and the increase was 25% in coarse rice cultivar Fakhr-e-Malakand and 4% in fine rice cultivar Basmati-385 (Fig. 5). The interaction of FYM x Zn indicated that grain filling duration increased with increasing Zn levels upto maximum Zn rate of 18 kg $ha^{-1}$ and the increase in grain filling duration was 15% more with application of FYM at the rate of 15 t $ha^{-1}$ as compared to 0 t FYM $ha^{-1}$ (Fig. 6).

FYM x Zn x C reflected that grain filling duration increased with increasing Zn levels upto maximum Zn rate of 18 kg $ha^{-1}$ at 0 t FYM $ha^{-1}$ and the increase was 11% in coarse rice cultivar Fakhr-e-Malakand and 8% in fine rice cultivar Basmati-385. Similarly, the grain filling duration increased with increasing of Zn application maximum upto 18 kg $ha^{-1}$ at 15 t FYM $ha^{-1}$ but the increase was 12% in fine rice cultivar Basmati-385 and 6% in coarse rice cultivar Fakhr-e-Malakand (Fig. 7).

Before the establishment of the experiments, soil samples were collected from five random locations in each plot and analyzed for the following physicochemical properties.

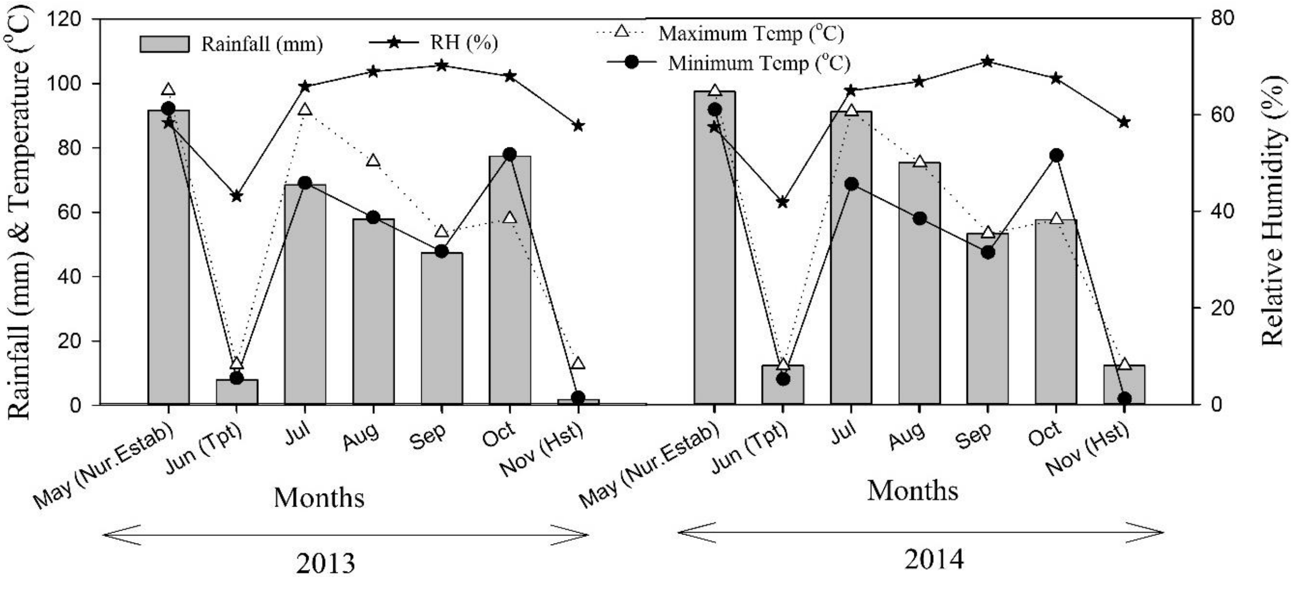


Fig. 1. Mean temperature, rainfall and relative humidity of experimental site for 2013 and 2014 during crop growth period.

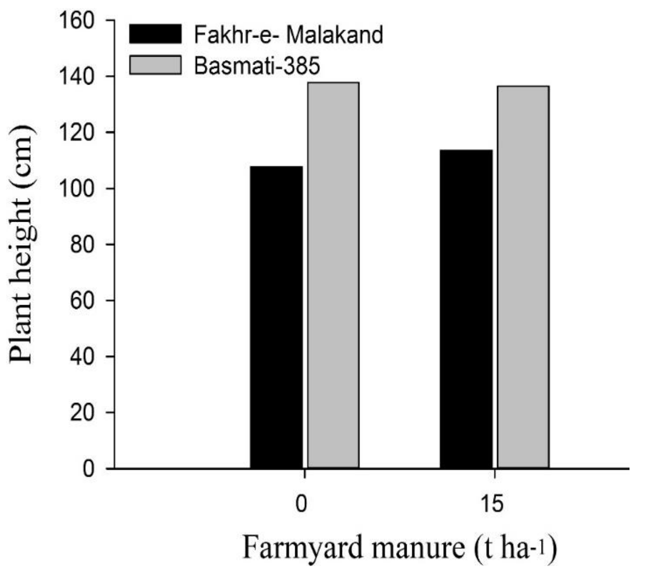


Fig. 2. FYM x C interaction for plant height of rice.

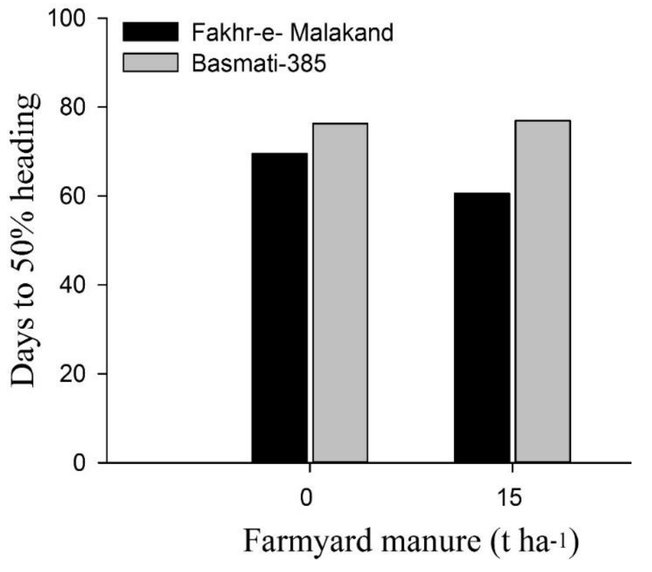


Fig. 3. FYM x C interaction for days to 50% heading in rice.

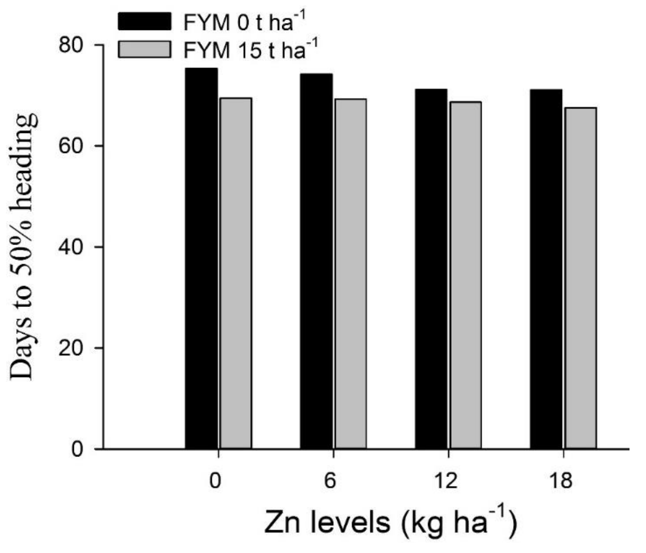


Fig. 4. FYM x Zn interaction for days to 50% heading in rice.

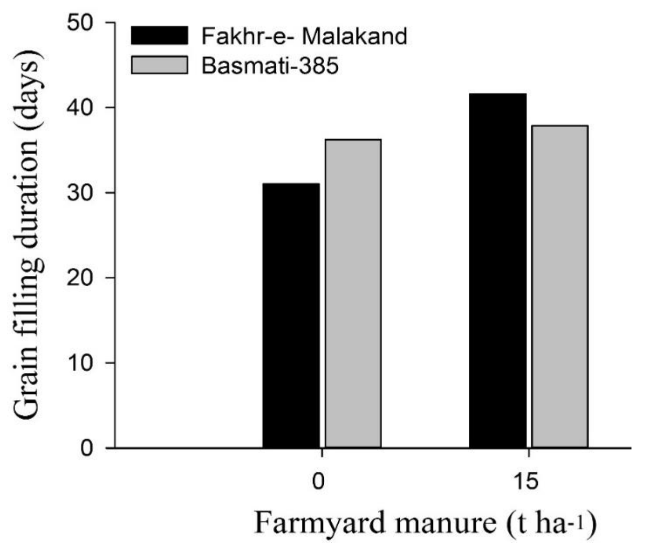


Fig. 5. FYM x C interaction for grain filling duration of rice.

**Table 4. Biological yield (kg ha$^{-1}$) and grain yield (kg ha$^{-1}$) of rice cultivars as affected by different FYM and Zinc levels during summer 2013 and 2014.**

| FYM (t ha$^{-1}$) | Biological yield (kg ha$^{-1}$) | Grain yield (kg ha$^{-1}$) |
|---|---|---|
| 0 | 12159 b | 5820 b |
| 15 | 18417 a | 8647 a |
| **Significance level** | ** | ** |
| **Rice cultivars** | | |
| Fakhr-e- Malakand | 16634 a | 7828 a |
| Basmati-385 | 13942 b | 6639 b |
| **Significance level** | ** | ** |
| **Zn levels (kg ha$^{-1}$)** | | |
| 0 | 14418 d | 6499 d |
| 6 | 15006 c | 7000 c |
| 12 | 15649 b | 7514 b |
| 18 | 16077 a | 7920 a |
| **LSD$_{(0.05)}$** | 198 | 92 |
| **Interactions** | | |
| Zn x C | ns | ns |
| FYM x C | * | ** |
| FYM x Zn | ** | ** |
| FYM x Zn x C | ns | ns |

"*" and "**" = Significant at 5 and 1% level of probability. "NS"= Non-significant

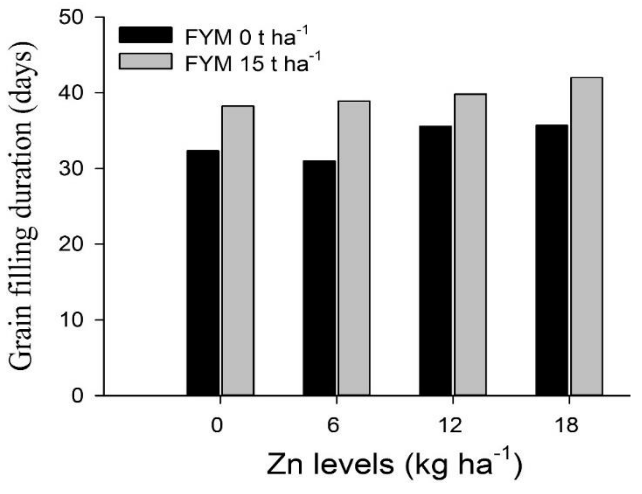


Fig. 6. FYM x Zn interaction for grain filling duration of rice.

**Days to physiological maturity:** Days to maturity of rice was significantly influenced by the main effects of FYM and cultivars (Table 3). The interactions of FYM x Zn, and FYM x Zn x C were significant but the remaining interactions were not significant. Rice cultivars took 106.6 days to reach maturity with the application of FYM at the rate of 50 t ha$^{-1}$ as compared to 108.5 days with 0 t FYM ha$^{-1}$. Cultivars differed significantly for days to maturity and the coarse rice cultivar Fakhr-e-Malakand matured in 101.4 days while fine rice cultivar Basmati-385 matured in 113.7 days.

The interaction of FYM x Zn revealed that days to maturity increased with increasing Zn levels upto maximum of Zn application at the rate of 18 kg ha$^{-1}$ and the increase was 1% with the application at 0 t FYM ha$^{-1}$ as compared to 2% increase with 15 t FYM ha$^{-1}$ (Fig. 8). The interactions among FYM x Zn x C revealed that Zn + FYM had no prominent effect on days to maturity but fine rice cultivar Basmati-385 took 13 days more to reach maturity than coarse rice cultivar Fakhr-e-Malakand (Fig. 9).

**Biological yield:** Statistical analysis of the data showed that FYM, cultivars and Zn levels significantly influenced biological yield (Table 4). The interactions between FYM x C and FYM x Zn, were significant while the remaining interactions were not significant. Biological yield of 18417 kg ha$^{-1}$ was produced with application of 15 t FYM ha-1 as compared to 12159 kg ha$^{-1}$ with 0 t FYM ha$^{-1}$. Coarse rice cultivar produced biological yield of 16634 kg ha$^{-1}$ as compared to 13942 kg ha$^{-1}$ produced by fine rice cultivar Basmati-385. Biological yield constantly increased from 14418 kg ha$^{-1}$ to 16077 kg ha$^{-1}$ with increasing levels of Zn upto maximum Zn rate 18 kg ha$^{-1}$.

Interaction between FYM x C indicated that biological yield increased with application of FYM at the rate of 15 t ha$^{-1}$ as compared to 0 t FYM ha$^{-1}$ and the increase was higher by 48% in coarse rice cultivar Fakr-e-Malakand 56% in fine rice cultivar Basmati-385 (Fig. 10). Interaction between FYM x Zn revealed that rice biological yield consistently increased with increase in Zn levels from 0 to 18 kg ha$^{-1}$. This increase 38% higher at 15 t FYM ha$^{-1}$ than at 0 t FYM ha$^{-1}$ (Fig. 11).

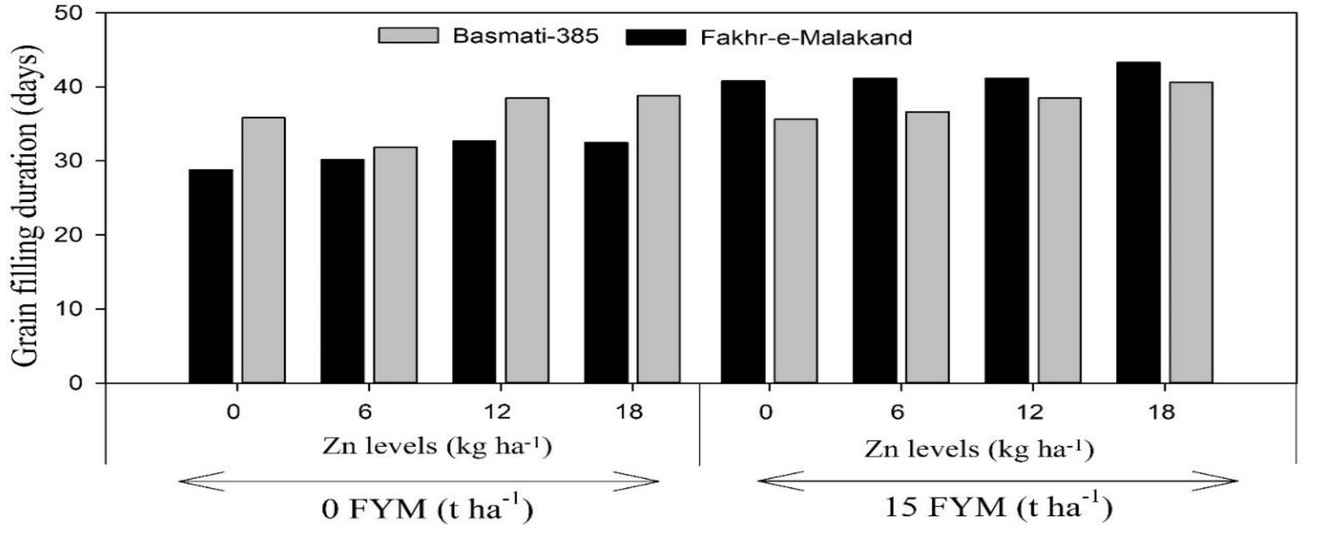


Fig. 7. FYM x Zn x C interaction for grain filling duration of rice.

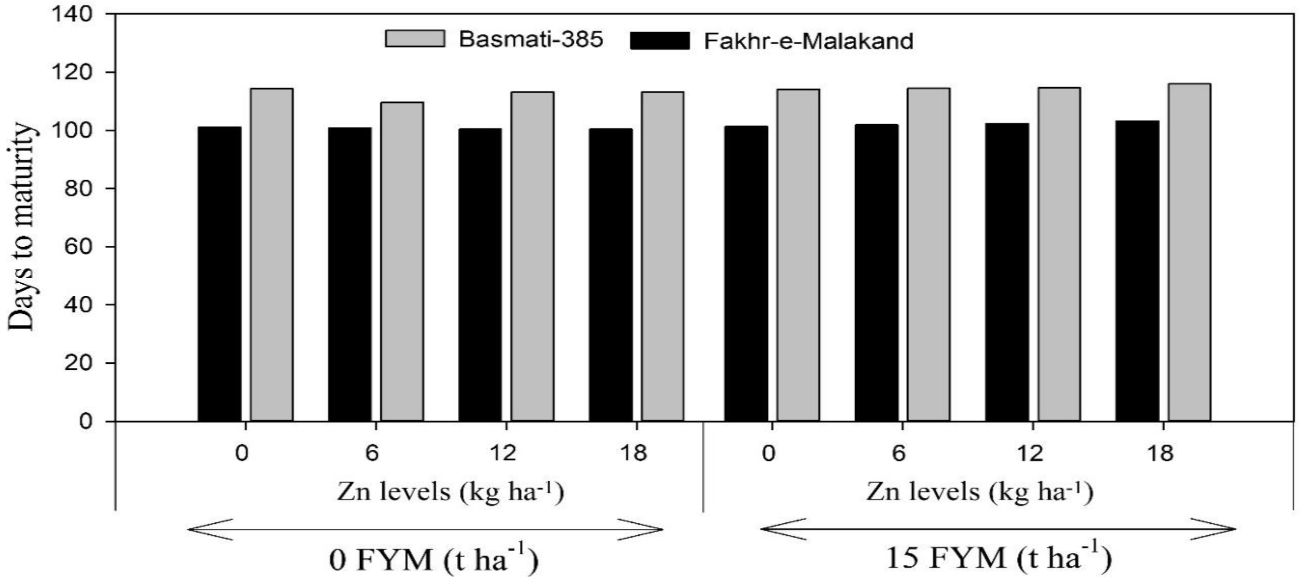


Fig. 9. FYM x Zn x C interaction for days to maturity of rice.

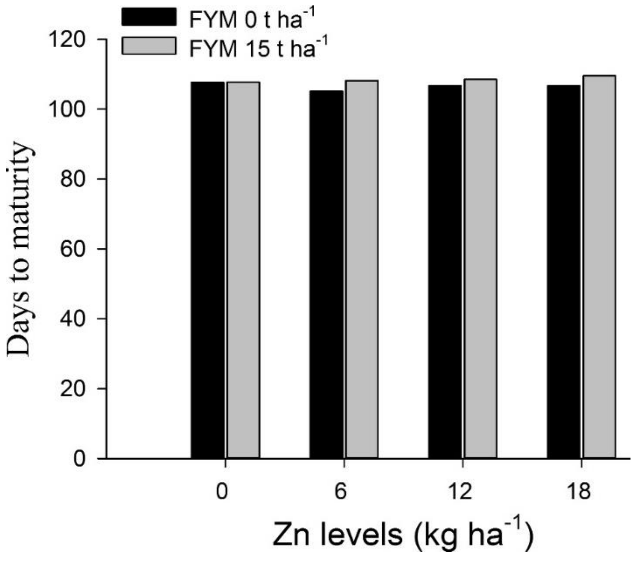


Fig. 8. FYM x Zn interaction for days to maturity of rice.

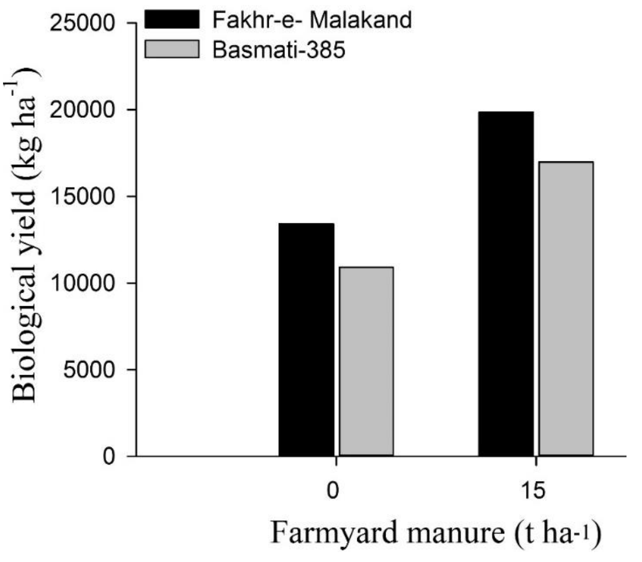


Fig. 10. FYM x C interaction for biological yield of rice.

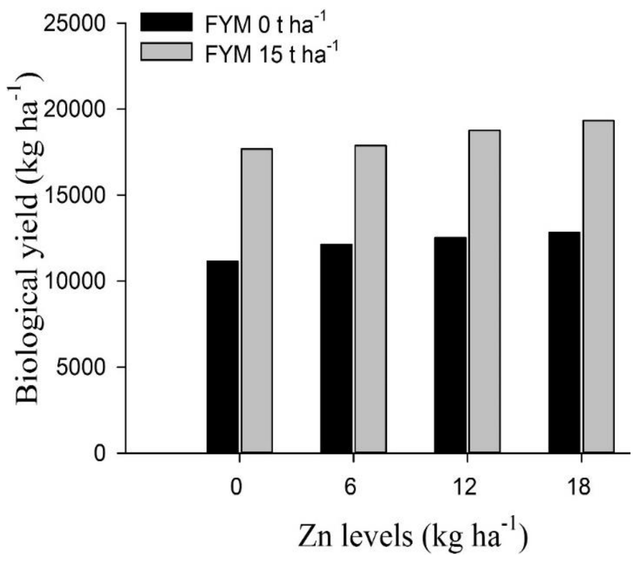


Fig. 11. FYM x Zn interaction for biological yield of rice.

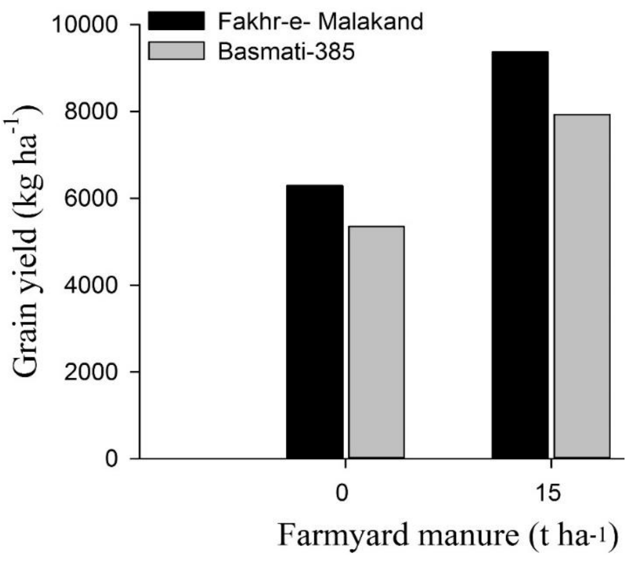


Fig. 12. FYM x C interaction for rice grain yield.

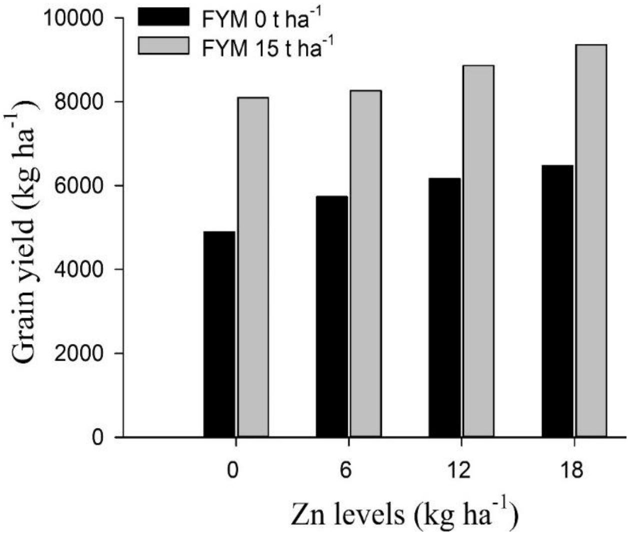


Fig. 13. FYM x Zn interaction for grain yield of rice.

**Grain yield:** Statistical analysis of the data revealed that FYM, cultivars and Zn levels significantly affected grain yield of rice (Table 4). Year as source of variation was not significant. The interactions of FYM x C and FYM x Zn, were significant while the rest of the interactions were not significant for rice grain yield. Application of FYM at the rate of 15 t $ha^{-1}$ increased grain yield of rice from 5820 to 8647 kg $ha^{-1}$ as compared to 0 t FYM $ha^{-1}$. Cultivars varied significantly for grain yield and the coarse cultivar Fakhr-e-Malakand produced grain yield of 7828 kg $ha^{-1}$ as compared to the grain yield of 6639 kg $ha^{-1}$ in fine cultivar Basmati-385. Grain yield consistently increased from 6499 to 7920 kg $ha^{-1}$ with increase in Zn levels upto maximum Zn rate of 18 kg $ha^{-1}$.

The interaction between FYM x C showed that grain yield increased with the application of FYM at the rate of 15 t FYM ha-1 as compared to 0 t FYM $ha^{-1}$ and the increase in grain yield was 14% higher in coarse rice cultivar Fakhr-e-Malakand than fine rice Basmati-385 (Fig. 12). The interaction of FYM and Zn interaction indicated that increasing Zn levels consistently increased grain yield with maximum Zn application at the rate of 18 kg $ha^{-1}$ and the increase 32% higher at 15 t FYM $ha^{-1}$ than at 0 t FYM $ha^{-1}$ (Fig. 13).

## Discussion

Plant height, grain filling duration and days to maturity increased but heading was hastened with supplementation of FYM to rice cultivars. Zn application increased plant height and grain filling duration while days to heading decreased. Basmati-385 produced taller plants, took longer to reach maturity and heading as compared to coarse rice cultivar Fakhr-e-Malakand. Increase in plant height with FYM application may be due to increased availability of soil nutrients as reported by Veeranagappa *et al.,* (2011) and Khan *et al.,* (2007) that compost enriched with different levels of Zn resulted into maximum plant height. The experimental results of delayed maturity with application of FYM are also in conformity with the research findings of Redda & Abay (2015) who reported that application of FYM with inorganic fertilizers delayed days to flowering and maturity. Taller plants, delayed maturity and days to heading in Basmati-385 as compared to coarse rice cultivar Fakhr-e-Malakand may be due to genetic characteristic of fine cultivars (Islam *et al*., 2012).

Biological yield of rice cultivars consistently increased with increase in Zn application. The cause of increased biological yield with Zn application may be due to enhanced uptake of Zn via roots and its translocation to vegetative parts (Rehman *et al.*, 2012). The results of experiment are in accordance with the research findings of Mustafa *et al.* (2011) and Tiwari (2002) who reported that highest biological yield was obtained at maximum Zn application. Latha *et al.*, (2002) reported residual effect of Zn-enriched organic manures on yield and Zn uptake in sunflower under maize-sunflower cropping sequence. Increasing biological yield with Zn application was also reported by Rashid (2001), Yan (2003) and Torun (2001). Application of Zn enriched FYM enhanced biological yield of rice cultivars which may be due to intermediate/ metabolites of decomposition of FYM that hold Zn in form available to plants or release Zn mobilizing compounds as phytosiderophores from roots, and induction of polypeptides involved in Zn uptake and translocation to shoots (Marschner, 1995; Cakmak *et al*., 2004). The results of experiment comply with the research findings of Ahmad *et al*., (2010) who reported that maximum straw and grain yields were achieved with treatments having $ZnSO_4$ in combination with FYM. Grain quality and size is an important yield parameter affecting the final grain yield. The grain yield increased with increase in Zn application, which may be due to major role of Zn during reproductive phase especially during fertilization as well as high presence of Zn in pollen grains as at the time of fertilization most of Zn is diverted to seed only (Singh *et al*., 2011). The results of the experiment are in conformity with the research investigation of Muthukumararaja and Sriramachandrasekharan (2012), Charati & Malakouti (2006), Chaudry & Singh (2007), Genc *et al*., (2002) and Jena *et al*., (2006) who reported increase in grain yield with Zn application. Zn enriched FYM increased grain yield by 49% as compared to control, which may be due to the positive effect of $ZnSO_4$ and organic matter in increasing Zn and other nutrients availability from soil and its partitioning to the reproductive parts of the plants (Maskina & Randhawa, 1983). The results are in harmony with the research findings of Ahmad *et al*., (2010) who reported that Zn sulphate-enriched farmyard manure significantly improved the grain and straw yield compared with control as well as with $ZnSO_4$ alone.

## Conclusion

It is concluded that Zn application at the rate of 18 kg $ha^{-1}$ increased plant height, grain filling duration, but hastened heading. Similarly, application of FYM at the rate of 15 t $ha^{-1}$ increased plant height, biological and grain yield with extended grain-filling duration, and shortened heading for coarse rice cultivar Fakhr-e-Malakand.

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