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Effect of Naphthalene Acetic Acid on yield and quality of Rice under different Phosphorus levels

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More than 50% of the world's population consumes rice and it is ranked as second staple food after wheat in Pakistan. Limited movement of beneficial assimilates from source to the sink in rice is major cause of less production. Foliar application of naphthalene acetic acid on rice influences its life cycle via metabolic processes through improvement in translocation of beneficial assimilates from source to sink, and hence enhancement in yield. To check the efficiency of exogenously applied naphthalene acetic acid on yield and quality of rice under different phosphorus levels, a pot experiment was carried out in kharif season 2019 at greenhouse/wire-house, Faculty of Agriculture, University of Agriculture, Faisalabad. Pots were arranged in completely randomized design with factorial treatments structure and three replications. Naphthalene acetic acid was applied as foliar spray (0, 100, 150, and 200 mg L^{-1}) at 60 days after sowing and different doses of phosphorus (0, 30, 60 and 90 kg ha^{-1}) were applied in soil at sowing. Using various standard procedures data were recorded regarding yield and quality of rice. All the acquired data were statistically examined by using Fisher's ANOVA method to check variability and variation between treatments means were compared at 5% probability level by using Tukey's HSD test. Plant height (134.7 cm), number of tillers per plant (10.4), number of panicles per plant (9.75), total grains per panicle (102.8), 1000-grain weight (30.3 g), normal kernels (76.12%), grain protein (9.54%) and grain phosphorus (2.51 mg g^{-1}) were best with 90 kg ha^{-1} phosphorus with 150 mg g^{-1} naphthalene acetic acid. Abortive kernels (6.28%), opaque kernels (10.99%) and chalky kernels (12.79%) were less at 90 kg ha^{-1} phosphorus with 150 mg g^{-1} naphthalene acetic acid and maximum at control condition. It was concluded that 90 kg ha^{-1} phosphorus with 150 mg g^{-1} naphthalene acetic acid improve agronomic, quality and seed quality parameters of rice crop**.**

Keywords: naphthalene acetic acid, rice, phosphorus

INTRODUCTION

Rice is being consumed by more than 50% of world population; 200 million poor households earn income and eat it for fulfilling their dietary needs (Muthayya et al. 2014). More than 50% of planet's population depends upon rice for food and nutritional requirements (Amprayn et al. 2012). Economy of Asian countries depends upon rice as a major export commodity and earns foreign exchange. In Asian countries poor people use rice straw to cover their roof tops and drink rice liquor. In cereals rice is second most significant crop after maize, which is globally produce and consumed (Awika et al. 2011). Increasing population day by day globally demands more food; To meet dietary needs; production of food needs to rise by 70% due to expected population of nine billion in 2050.

In plants different physiological processes require phosphorus for their optimum work; phosphorus is essential part of numerous enzymes which takes part in structural components of nucleic acid (DNA or RNA) and growth (Gamuyao et al. 2012). Inadequate phosphorus availability to plants causes various disorders such as improper development and growth of roots, maximum shedding of flowers, decrease lodging resistance, decreased grain filling percentage, grain weight decrease, thin seedlings and poor-quality seed. Hence, for enhancing crop productivity we need to improve phosphorus use efficiency (Alinajati et al. 2011).

Phosphorus enhances root growth, prevents late maturity and enhances production. Straw strength can be increased by phosphorus application in rice and it increases resistance in plants against lodging, stress and various diseases. Phosphorus improves the yield traits in rice, decreases cost of production and also causes less environmental pollution (Liang et al. 2006). Phosphorus application on early stages of rice significantly enhances grain yield and dry matter in developmental stages (Maitiet al. 2011). Plant heights, number of tillers, grains per panicle and grain weight are enhanced by phosphorus application in rice (Golam et al. 2011; Golam et al. 2012). Maximum number of panicles per square meter, less sterility of kernels, maximum grains per panicle and more 1000-grain weight are achieved by optimum phosphorus application in rice (Bakhsh et al. 2011; Bakhsh et al. 2012).

Besides horticultural crops naphthalene acetic acid plays a vital role in several agronomic crops by affecting their metabolic activities and improving in yield traits that lead to more yield in crops (Khanzada et al. 2002). Naphthalene acetic acid enhances the yield traits in rice by stimulating the root activities and enhances the efficiency of root working mechanism, boosts up growth and development by delaying senescence, increasing grain weight and grain yield due to movement of beneficial assimilates from source to sink (Zhi-Guo et al. 2012). Phosphorus uptake is enhanced by foliar application of naphthalene acetic acid in plants which is required by plants for their photosynthetic activity and maintains their optimum photosynthesis level (Qazi et al. 2013). Phosphorus uptake in plants was observed maximum at panicle initiation stage in rice crop when naphthalene acetic acid was foliar applied (Chen et al.2007; Chin et al. 2010; Chin et al. 2011).

For increasing rice production several types of researches have been done to increase the nutrients use efficiency. Still, there is a lack of research about major nutrients especially phosphorus along with naphthalene acetic acid in rice crop to enhance phosphorus use efficiency and management.

Specific objectives of this study:

1. To optimize dose of exogenously applied naphthalene acetic acid to enhance the yield of rice.
2. To introduce low input (P) technology for attaining maximum yield potential of Basmati rice by the use of naphthalene acetic acid.

MATERIALS AND METHODS

A pot experiment was conducted under factorial completely randomized design (CRD) with three repetitions to check the response of rice crop to foliar naphthalene acetic acid spray (0, 100, 150, and 200 mg L^{-1}) at 60 days after sowing under different doses of phosphorus (0, 30, 60 and 90 kg ha^{-1}) which were applied in soil at sowing.

Analysis of soil:

Before transplanting seedlings of rice into pots, analysis of soil (physico-chemical) was conducted to know about soil type and its properties. Soil auger was used to cut soil up to fifteen- and thirty-centimeters depth, from which composite and representative soil samples were collected from where soil was taken to fill up pots. Soil sample was analyzed for various physiochemical properties and results are given in table 1.

Table 1: Analysis of soil (physico-chemical) before seedling transplanting

Characteristics	Unit	Value obtained	Status
Texture	-	-	Sandy loam
pH	-	8.21	Alkaline
Sand	%	33.79	-
Silt	%	34.13	-
Clay	%	32.24	-
EC	dS/m	1.3	Normal
Organic matter	%	0.92	Low
Nitrogen (N)	%	0.058	Low
Phosphorus (P)	ppm	8.9	Low
Potassium (K)	ppm	166	Sufficient

Data recording:

Agronomic parameters:

Height of plant (cm), number of tillers per plant, number of panicles per plant, length of panicle (cm), total grains per panicle, filled grains per panicle, weight of 1000 grains (g) and yield per plant (g) were taken at maturity.

Biochemical and quality parameters:

Grain protein contents (%)

Micro-Kjeldhal apparatus was used for digestion of rice grains followed by ammonia distillation and titration to determine nitrogen concentration. This nitrogen concentration was then multiplied with 6.25 to obtain protein content of grains.

Grain phosphorus (mg g^{-1})

Spectrophotometer apparatus was used to determine the rice grain phosphorous content which was followed by wet digestion.

Normal kernels (%):

Translucent kernels that attained full size and have compact starch to allow light to pass are called normal kernels. These were counted by subtracting the opaque, abortive and chalky kernels from total kernels and expressed in percentage.

Abortive kernels (%):

Those kernels that do not attain full size due to incomplete fertilization are abortive kernels. On working board twenty grains were put in front of light (Tungsten filament). Percentage of abortive kernels was calculated by counting abortive kernels.

Opaque kernels (%):

When kernels were positioned in front of light bulb and they do not allow light to pass are opaque kernels. This occurs due to absence of carbohydrate. Opaque kernels were counted by placing twenty kernels on working board in front of light bulbs and expressed in percentage.

Chalky kernels (%)

Kernels parted on the base of existence of chalkiness on kernels are called chalky kernels. Chalky kernels were identified from twenty kernels that were placed on working board in front of light bulb. These chalky kernels were expressed in proportion.

Statistical analysis:

Fisher's analysis of variance technique (Steel et al. 1997) was used to analyze recorded data statistically ($p \leq 0.05$) and Tukey's Honestly Significant Difference (Tukey's HSD) test was used to compare the means at 5% probability level. While STATISTIX 8.1 software (Gomez and Gomez, 1984) was employed for analysis of variance and comparison of treatments' means.

RESULTS AND DISCUSSION

Height of plant (cm):

Height of plant is a vital morphological character and it is affected by both genetic make-up and ambient environmental conditions like availability of nutrients in soil, vigor of seedling and stresses that may hamper the growth of plant. Data presented in table 2 show that effect of naphthalene acetic acid and different phosphorus levels on plant height of rice was significant. However, their interactive effect was non-significant on this parameter.

Maximum plant height (134.7 cm) was calculated in P_3 (90 kg/ha phosphorus) treatment; plant height decreases by decreasing phosphorus dose while minimum plant height (118.4 cm) was obtained by P_0 (0 kg/ha phosphorus) treatment. Application of naphthalene acetic acid enhanced plant height and maximum height of rice plant (129.2 cm) was observed in NAA_2 treatment, where naphthalene acetic acid was applied at the rate of 150 ppm concentration and minimum plant height (125.2cm) was noted in NAA_0 treatment, where no naphthalene acetic acid was applied (table 3).

Phosphorus enhances the growth of rice and other crops and increases plant height when applied with naphthalene acetic acid. Adequate availability of phosphorus to rice plant develops better root system in plants which leads to increased uptake of nutrients from soil and also enhances the yield and yield components (plant height, number of grains per panicle, 1000-grain weight, dry matter) of rice crop (Sharma et al. 2010).

Results of our experiment were same as those of Jahan et al. (2011) who documented that under different phosphorus levels with naphthalene acetic acid, plant height was increased due to enhanced photosynthetic activity and translocation of beneficial assimilates from source to sink.

Naphthalene acetic acid enhanced the plant height in rice when applied at low concentration (100 and 150 ppm) with different phosphorus levels as reported by Danica *et al.* (2003). Results of our experiment were same as those of Bakhsh *et al.* (2011) who also documented that plant growth regulators (gibberalic acid and naphthalene acetic acid) when applied at less concentration on rice crop enhanced its height up to 130 cm in coarse rice variety IR-6 at maturity level. Results of our experiment were same as those of Golam *et al.* (2011) who documented that plant height in rice was significantly increased by 150 ppm of naphthalene acetic acid with different irrigation regimes.

Number of tillers per plant:

Plant population is one of the most important factors that contribute towards yield; in case of rice, population of plants mainly depends upon number of tillers per plant. Higher the number of tillers per plant more will be the grains was attained that leads to high yield and vice-versa. Data presented in table 2 show that effect of naphthalene acetic acid and different phosphorus levels on number of tillers per plant of rice was significant. However, their interactive effect was non-significant on this parameter.

Maximum number of tillers per plant (10.4) was seen in P_3 (90 kg/ha phosphorus) treatment; number of tillers decreases by decreasing phosphorus dose while minimum number of tillers per plant (6.3) was obtained by P_0 (0 kg/ha phosphorus) treatment. Application of naphthalene acetic acid enhanced number of tillers per plant and maximum number of tillers per plant (8.7) was calculated in NAA_2 treatment, where naphthalene acetic acid was applied at the rate of 150 ppm concentration although it was statistically similar to other two doses (100 and 200 ppm) of NAA. While minimum number of tillers per plant (7.8) was noted in NAA_0 treatment, where no naphthalene acetic acid was applied (table 3).

Rice plant requires more phosphorus as compared to other crops for building their fertile and healthy tillers; sufficient phosphorus availability to rice crop develops its better root system, providing resistance against stress, that leads to increased up taking of nutrients from soil to plant parts and also enhances the number of tillers per plant in rice crop (Zhi et al. 2012). Results of our experiment were same as those of Liu et al. (2011) who documented that total number of tillers per plant was significantly increased when naphthalene acetic acid was applied at panicle initiation stage on rice crop because naphthalene acetic acid delayed the senescence during tillering stage and provided resistance against stress.

When naphthalene acetic acid was applied at low concentration (100 and 150 ppm) it enhanced the total number of tillers per plant in rice under different phosphorus levels and irrigation levels as reported by Danica et al. (2003). Results of our experiment were same as those of Golam et al. (2011) who also documented that maximum number of tillers per plant was attained by 150 ppm of naphthalene acetic acid on rice crop, high concentration of naphthalene acetic acid reduced crop growth which was also observed in present study.

Results of another experiment were shown that number of tillers per plant in rice was significantly enhanced by 100 and 150 ppm of naphthalene acetic acid under different phosphorus levels (Chaudhuri et al. 1980). Exogenously application of naphthalene acetic acid (150 ppm) on rice crop enhanced the growth of productive tillers and decreased the growth of unproductive tillers (Bakhsh et al. 2011).

Number of panicles per plant:

Yield of rice is associated with number of panicles per plant and generally number of panicles per plant is a genetically controlled trait in rice but when sufficient nutrition is provided, this trait is improved and leads to high yield. Data presented in table 2 show that effect of naphthalene acetic acid and different phosphorus levels on number of panicles per plant of rice was significant. However, their interactive effect was non-significant on this parameter.

Maximum number of panicles per plant (9.75) was calculated in P_3 (90 kg/ha phosphorus) treatment; number of panicles per plant decreases by decreasing phosphorus dose while minimum number of panicles per plant (6.11) was obtained by P_0 (0 kg/ha phosphorus) treatment. Application of naphthalene acetic acid enhanced number of panicles per plant and maximum number of panicles per plant (8.13) was noted in NAA_2 treatment, where naphthalene acetic acid was applied at the rate of 150 ppm concentration and minimum number of panicles per plant (7.33) was noted in NAA_0 treatment, where no naphthalene acetic acid was applied (table 3).

Naphthalene acetic acid when applied at low concentration along with phosphorus it increases the metabolic activities of rice plant and enhances the up taking ability of nutrition from soil by developing plants roots; due to improved mechanism of up taking minerals, plant growth rate increases up to maximum level that leads to more number of panicles per plant and ultimately enhances yield (Campanoni et al. 2005).

Results of our experiment were same as those of Jahan et al. (2011) who documented that under different phosphorus levels with naphthalene acetic acid, number of panicles per plant was increased due to enhanced photosynthetic activity and translocation of beneficial assimilates from source to sink.

Naphthalene acetic acid enhanced the number of panicles per plant in rice when applied at low concentration (100 and 150 ppm) with different phosphorus levels as reported by Danica et al. (2003). Results of our experiment were same as those of Bakhsh et al. (2012) who also documented that plant growth regulators (gibberellic acid and naphthalene acetic acid) when applied at less concentration on rice crop enhanced number of panicles per plant up to maximum level in coarse rice variety IR-6 at maturity level.

Islam et al. (2005) documented that naphthalene acetic acid and gibberellic acid when applied at low concentration on rice crop increased the number of panicles per plant in rice crop under different phosphorus levels; these growth substances not only enhanced number of panicles per plant but also improve overall growth and yield of rice crop.

Length of panicle (cm):

Panicle length is important attribute towards yield because more the panicle length higher will be the number of kernels per panicle that leads to maximum yield and vice-versa. Data presented in table 2 show that effect of naphthalene acetic acid and different phosphorus levels on panicle length of rice was significant. However, their interactive effect was non-significant on this parameter.

Maximum length of panicle (30.81 cm) was seen in P_3 (90 kg/ha phosphorus) treatment; length of panicle decreases by decreasing phosphorus dose while minimum length of panicle (22.48 cm) was obtained by P_0 (0 kg/ha phosphorus) treatment. Application of naphthalene acetic acid enhanced length of panicle and maximum length of panicle (27.78 cm) was observed in NAA_2treatment, where naphthalene acetic acid was applied at 150 ppm concentration and minimum length of panicle (26.15 cm) was noted in NAA_0 treatment, where no naphthalene acetic acid was applied (table 3).

Length of panicle is important attribute towards yield in rice crop, foliar applied naphthalene acetic acid on rice crop at low concentration (100 and 150 ppm) at panicle initiation stage increases the panicle length up to maximum. Phosphorus uptake from soil to growing plant parts is rapid when naphthalene acetic acid contacts with crop and boosts its metabolic activities and causes in delay in growing speed for maximum buildup of plant matter.

Naphthalene acetic acid is a high efficiency auxin and enhance the auxin level in plant body by generating auxin through shikimate pathway in plastids and then it is transferred to cytosol; some quantity of auxin is degraded with sugars and some are bonded with amino acids, remaining part of auxin is used for enhancing growth and development of rice plant (Zhi-Guo et al. 2012). Results of our experiment were same as those of Golam et al. (2011) who documented that under different phosphorus levels with naphthalene acetic acid, length of panicle was increased due to enhanced photosynthetic activity and translocation of beneficial assimilates from source to sink.

Naphthalene acetic acid enhanced the panicle length (cm) in rice when applied at low concentration (100 and 150 ppm) with different phosphorus levels as reported by Danica et al. (2003). Results of our experiment were same as those of Liu et al. (2012) who documented that, panicle length in rice plat significantly enhanced upto maximum length when naphthalene acetic acid (150 ppm) applied at less concentration with different phosphorus levels. Results of our experiment were same as those of Bakhsh et al. (2011) who also documented that plant growth regulators (gibberellic acid and naphthalene acetic acid) when applied at less concentration on rice crop enhanced its panicle length in coarse rice variety IR-6.

Total grains per panicle:

Production of cereal crops depends upon different parameters. Total grains contribute towards yield of rice. More the number of grains per panicle higher will be paddy production and in case of few or less number of filled grains lower will be yield of rice. Data presented in table 2 show that effect of naphthalene acetic acid and different phosphorus levels on total grains per panicle of rice was significant. However, their interactive effect was non-significant on this parameter.

Maximum number of grains per panicle (102.8) was calculated in P_3 (90 kg/ha phosphorus) treatment; number of grains per panicle decreases by decreasing phosphorus dose while minimum number of grains per panicle (66.0) was obtained by P_0 (0 kg/ha phosphorus) treatment. Application of naphthalene acetic acid enhanced number of grains per panicle and maximum number of grains per panicle (89.0) were produced in NAA_2 treatment, where naphthalene acetic acid was applied at the rate of 150 ppm concentration and minimum number of grains per panicle (81.3) was noted in NAA_0 treatment, where no naphthalene acetic acid was applied (table 3).

Phosphorus enhances the growth of rice and other crops and contributes to attain high yield by more food movement from soil to developing parts of plant. Results of our experiment were same as those of Liu et al. (2012) who documented that under different phosphorus levels with naphthalene acetic acid, total grains per panicle were increased due to enhanced photosynthetic activity and translocation of beneficial assimilates from source to sink.

An experiment was conducted by Danica et al. (2003) to check the effects of naphthalene acetic acid on morphological and yield attributes of rice; results of this experiment indicate that naphthalene acetic acid significantly enhanced the total grains per panicle because naphthalene acetic acid enhances the movement of beneficial assimilates from soil to developing parts of plant during their growth period and delayed the senescence and maturity time which enhanced the period of growth that leads to more assimilation of food towards grains at grain filling period.

Naphthalene acetic acid enhanced the total grains per panicle in rice when applied at low concentration (100 and 150 ppm) with different phosphorus levels as reported by Biswas et al. (1978). Results of our experiment were same as those of Golam et al. (2011) who documented that low concentration of naphthalene acetic acid (100 and 200 ppm) on rice under different phosphorus and irrigation levels enhanced the number of grains per panicle in rice crop up to maximum level in BARRIdhan-29.

Filled grains per panicle:

Production of cereal crops depends upon different parameters. Filled grains per panicle are of prime importance; more filled grains per panicle means more economic yield and vice versa. Data presented in table 2 show that effect of naphthalene acetic acid and different phosphorus levels on filled grains per panicle of rice was significant. However, their interactive effect was non-significant on this parameter.

Maximum filled grains per panicle (95.3) were noted in P_3 (90 kg/ha phosphorus) treatment; filled grains per panicle were decreased by decreasing phosphorus dose while minimum number of filled grains per panicle (59.3) was obtained by P_0 (0 kg/ha phosphorus) treatment. Application of naphthalene acetic acid enhanced number of filled grains per panicle and maximum number of filled grains per panicle (81.8) were obtained in NAA_2 treatment, where naphthalene acetic acid was applied at 150 ppm concentration and minimum number of filled grains per panicle (73.3) was noted in NAA_0 treatment, where no naphthalene acetic acid was applied (table 3).

Phosphorus enhances the growth of rice and other crops and increases resistance against stress when applied with naphthalene acetic acid. Results of our experiment were same as those of Bakhsh *et al.* (2012) who documented that under different phosphorus levels with naphthalene acetic acid, number of filled grains per panicle was increased due to enhanced photosynthetic activity and translocation of beneficial assimilates from source to sink. Naphthalene acetic acid enhanced the number of filled grains per panicle in rice when applied at low concentration (100 and 150 ppm) with different phosphorus levels as reported by Golam *et al.* (2011).

An experiment was conducted by Danica *et al.* (2003) to check the effects of naphthalene acetic acid on morphological and yield attributes of rice; results of this experiment indicate that naphthalene acetic acid significantly enhanced the percentage of filled grains per panicle because naphthalene acetic acid enhances the movement of beneficial assimilates from soil to developing parts of plant during their growth period.

Weight of 1000 grains (g):

Production of cereal crops depends upon different parameters. Weight of 1000 grains is of prime importance; heavier the grains/kernels more will be the economic yield and vice versa. Data presented in table 2 show that effect of exogenously applied naphthalene acetic acid and different phosphorus levels on 1000-grain weight of rice was significant. However, their interactive effect was non-significant on this parameter.

Maximum 1000-grain weight (30.3 g) was calculated in P_3 (90 kg/ha phosphorus) treatment; 1000-grain weight decreases by decreasing phosphorus dose while minimum 1000-grain weight (25.4 g) was obtained by P_0 (0 kg/ha phosphorus) treatment. Application of naphthalene acetic acid enhanced 1000-grain weight upto a level and maximum grain weight (28.4 g) was calculated in NAA_2 treatment, where naphthalene acetic acid was applied at the rate of 150 ppm concentration and minimum 1000-grain weight (27.5 g) was noted in NAA_0 treatment, where no naphthalene acetic acid was applied (table 3).

Phosphorus enhances the growth of rice and other crops and increases resistance against stress when applied with naphthalene acetic acid. Results of our experiment were same as those of Bakhsh et al. (2011) who documented that under different phosphorus levels with naphthalene acetic acid, seed weight was increased due to enhanced photosynthetic activity and translocation of beneficial assimilates from source to sink. Naphthalene acetic acid enhanced the 1000-grain weight in rice when applied at low concentration (100 and 150 ppm) with different phosphorus levels as reported by Golam *et al.* (2011).

Another experiment was conducted by Sarker*et al.* (2013) to check the efficiency of root growth and yield of rice under different irrigation regimes and growth regulators (naphthalene acetic acid and gibberlic acid); result of this experiment indicate that 1000-grain weight (g) of rice enhanced up to maximum level when naphthalene acetic acid was applied at panicle initiation stage in rice crop. Results of our experiment were same as those of Liu *et al.* (2012) who documented that maximum 1000-grain weight (g) was obtained by foliar application of naphthalene acetic acid on rice crop at 60 DAS (panicle initiation stage) under different growth regulators.

Results of our experiment were same as those of Jahan *et al.* (2011) who documented that under different phosphorus levels with naphthalene acetic acid, 1000-grain weight was increased due to enhanced photosynthetic activity and translocation of beneficial assimilates from source to sink.

Results of another experiment showed a slight increase in 1000 grain weight in rice and significant increase in 1000 grain weight in rice variety Mahsuri when foliar application of 100 ppm naphthalene acetic acid was done (Chaudhuri *et al.* 1980).

Result of an experiment showed that combined effect of 150 ppm foliar applied naphthalene acetic acid and irrigation intervals significantly enhanced 1000-grain weight in rice crop (Zhi*et al.* 2012). Results of another experiment showed that combined effect of 100 and 150 pm of naphthalene acetic acid and different phosphorus levels significantly enhanced 1000-grain weight up to maximum level in rice variety IR-6 (Zahir*et al.* 1998).

Yield per plant (g):

Grains /kernels are the economic produce of crop on which farmers pay their most of attention to improve. It is affected by number of external and internal factors. Kernel yield depends upon fertile tillers, grains per panicle and 1000-grain weight. Data presented in table 2 show that effect of naphthalene acetic acid and different phosphorus levels on plant of rice was significant. However, their interactive effect was non-significant on this parameter.

Maximum yield per plant (33.42 g) was obtained in P_3 (90 kg/ha phosphorus) treatment; yield per plant decreases by decreasing phosphorus dose while minimum yield per plant (26.13 g) was obtained by P_0 (0 kg/ha phosphorus) treatment. Application of naphthalene acetic acid enhanced grain yield per plant and it was maximum (32.70 g) was calculated in NAA_2 treatment, where naphthalene acetic acid was applied at the rate of 150 ppm concentration and minimum yield per plant (27.79 g) was noted in NAA_0 treatment, where no naphthalene acetic acid was applied (table 3).

Phosphorus is very essential nutrient which is required by plants for their normal growth and better grain filling. In rice crop grain filling period is most important because it leads to maximum and minimum yield according it its filling rate per plant; naphthalene acetic acid when applied at low concentration (100 and 150 ppm) on rice crop it enhance the movement of beneficial assimilates from soil to grains during grain filling stage of rice, it also prevents rice from stress and senescence

Quality parameters:

Normal kernels:

These are translucent kernels that attain full size and allow light to pass through them. Data presented in table 2 show that effect of naphthalene acetic acid and different phosphorus levels on normal kernels of rice was significant. However, their interactive effect was non-significant on this parameter.

Maximum normal kernels (76.12%) was calculated in P_3 (90 kg/ha phosphorus) treatment; normal kernels decrease by decreasing phosphorus dose while minimum normal kernels (59.68%) was obtained by P_0 (0 kg/ha phosphorus) treatment. Application of naphthalene acetic acid enhanced normal kernels percentage and maximum normal kernels (72.63%) were found in NAA_2 treatment, where naphthalene acetic acid was applied at the rate of 150 ppm concentration and minimum normal kernels (65.07%) was noted in NAA_0 treatment, where no naphthalene acetic acid was applied (table 3).

Rice quality was greatly affected by abiotic factors that might be due to hampered physiological processes such as photosynthesis and transpiration that led to disturbed grain filling. Improvement in normal kernels with naphthalene acetic acid application might be due to its role as nutrients and carbon source (Xu *et al.* 2008; Yang *et al.* 2013) that improved quality of grain.

Abortive kernels:

The grains in which fertilization takes place but during early phase of development they stop growing and fail to attain full size are regarded as abortive kernels. They do not allow sunlight to pass through them and look dull. Data presented in table 2 show that effect of naphthalene acetic acid and different phosphorus levels on percentage of abortive kernels of rice was significant and their interactive effect was also significant on this parameter (table 3).

Significantly highest percentage of abortive kernels (6.28%) was calculated in P_0 (0 kg/ha phosphorus) treatment; it was observed that abortive kernels increased by decreasing phosphorus dose so minimum abortive kernels (1.68%) were obtained by P_3 (90 kg/ha phosphorus) treatment. Application of naphthalene acetic acid reduced abortive kernels and minimum percentage of abortive kernels (2.96%) was calculated in NAA_2 treatment, where naphthalene acetic acid was applied at the rate of 150 ppm concentration and maximum abortive kernels (4.76%) were noted in NAA_0 treatment, where no naphthalene acetic acid was applied. Interaction values show minimum abortive ker(Campanoni et al. 2005).

Results of our experiment were same as those of Sarker et al. (2013) who documented that under different phosphorus levels with naphthalene acetic acid, yield per plant was increased due to enhanced photosynthetic activity and translocation of beneficial assimilates from source (leaves) to sink (grain). Naphthalene acetic acid is involved in metabolic activities in plants, generates energy rich phosphate and supplies energy for physiological processes. It increases resistance against senescence, enhances growth rate, improve stimulation of nutrients from plant parts to grains which leads to more filled grains per plant and leads to maximum yield in rice crop; significant effect of naphthalene acetic acid were recorded when applied at panicle initiation stage in rice crop (Golam et al. 2012).

Naphthalene acetic acid enhanced the yield per plant in rice when it was applied at low concentration (100 and 150 ppm) with different phosphorus levels as reported by Danica et al. (2003). Results of our experiment were similar to those of Bakhsh et al. (2012) who also documented that plant growth regulators (gibberellic acid and naphthalene acetic acid) when applied at less concentration on rice crop enhanced yield per plant up to maximum level in coarse rice variety IR-6.

Phosphorus enhances the growth of rice and other crops and contributes to attain high yield by more food movement from soil to developing parts of plant when added with naphthalene acetic acid. Results of our experiment were similar as those of Bakhsh et al. (2012) who documented that under different phosphorus levels with naphthalene acetic acid, percentage of abortive kernels was decreased due to enhanced photosynthetic activity and translocation of beneficial assimilates from source to sink.

Opaque kernels:

Kernels that lack carbohydrate/starch and are not translucent but still attain full size are placed under opaque kernels category. Opaqueness is an unwanted attribute of rice. These grains did not allow light to pass due to dull structure and lack of starch. Data presented in table 2 show that effect of naphthalene acetic acid and different phosphorus levels on percentage of opaque kernels of rice was significant and their interactive effect was also significant on this parameter.

Maximum opaque kernels (10.99 %) were found in P_0 (0 kg/ha phosphorus) treatment; opaque kernels increased by decreasing phosphorus dose while minimum opaque kernels (4.84%) were obtained by P_3 (90 kg/ha phosphorus) treatment. Application of naphthalene acetic acid reduced opaque kernels and minimum percentage of opaque kernels (4.80%) was calculated in NAA_2 treatment, where naphthalene acetic acid was applied at the rate of 150 ppm concentration and maximum opaque kernels (10.49%) was noted in NAA_0 treatment, where no naphthalene acetic acid was applied. Interaction values show minimum opaque kernels percentage in treatment combination P_3NAA_2 (90 kg P ha^{-1} along with 150 mg L^{-1} NAA) while application of no P and no NAA resulted in maximum opaque kernels (13.84%) (table 3).

Phosphorus enhances the growth of rice and other crops and contributes to attain high yield by more food movement from soil to developing parts of plant when added with naphthalene acetic acid. Results of our experiment were same as those of Liu *et al.* (2012) who documented that under different phosphorus levels with naphthalene acetic acid, percentage of opaque kernels was decreased due to enhanced photosynthetic activity and translocation of beneficial assimilates from source to sink.

Chalky kernels:

Kernels having chalkiness on kernels came under chalky grains category. Chalkiness is an undesired and unwanted character that reduces value of rice. Stressful environment positively impacts chalkiness. Data presented in table 2 show that effect of naphthalene acetic acid and different phosphorus levels on percentage of chalky kernels of rice was significant, and their interactive effect was non-significant on this parameter.

Maximum chalky kernels (12.79%) were seen in P_0 (0 kg/ha phosphorus) treatment; chalky kernels increase by decreasing phosphorus dose while minimum chalky kernels (4.91%) was obtained by P_3 (90 kg/ha phosphorus) treatment. Application of naphthalene acetic acid reduced production of chalky kernels and minimum chalky kernels (6.20%) were seen in NAA_2 treatment, where naphthalene acetic acid was applied at the rate of 150 ppm concentration and maximum chalky kernels (10.97%) were noted in NAA_0 treatment, where no naphthalene acetic acid was applied (table 3).

Phosphorus enhances the growth of rice and other crops and increases resistance against stress when applied with naphthalene acetic acid, it improves the structure of rice kernel by maximum translocation of beneficial assimilates from source to sink (Bakhsh *et al.* 2011). Result of our experiment were same as those of Liu *et al.* (2012) who documented that minimum percentage of chalky kernels was obtained by foliar application of naphthalene acetic acid on rice crop at 60 DAS (panicle initiation stage).

Seed analysis:

Grain protein (%):

Grain protein is desired character and quality of rice is greatly influenced by grain protein contents. Phosphorus and application of naphthalene acetic acid (150 ppm) had significant effect on protein percentage of grains. Data presented in table 2 show that effect of naphthalene acetic acid and different phosphorus levels on grain protein percentage of rice was significant. However, their interactive effect was non-significant on this parameter.

Maximum grain protein percentage (9.54) was calculated in P_3 (90 kg/ha phosphorus) treatment; grain protein percentage decreases by decreasing phosphorus dose while minimum grain protein percentage (6.07) was obtained by P_0 (0 kg/ha phosphorus) treatment. Application of naphthalene acetic acid enhanced grain protein percentage and maximum grain protein percentage (8.49) was observed in NAA_2 treatment, where naphthalene acetic acid was applied at the rate of 150 ppm concentration and minimum grain protein percentage (7.37) was noted in NAA_0 treatment, where no naphthalene acetic acid was applied (table 3).

Adequate availability of phosphorus to rice plant develops better root system in plants which leads to increased uptake of nutrients from soil and also enhances the nutrition and yield components (number of grains per panicle, 1000-grain weight, grain protein, dry matter) of rice crop (Sharma *et al.* 2010; Yu *et al.* 2016). Results of our experiment were same as those of Jahan *et al.* (2012) who documented that under different phosphorus levels with naphthalene acetic acid, grain protein percentage was increased due to enhanced photosynthetic activity and translocation of beneficial assimilates from source (leaves) to sink (seeds).

Naphthalene acetic acid enhanced the grain quality in rice when applied at low concentration (100 and 150 ppm) with different phosphorus levels as reported by Danica *et al.* (2003). Results of our experiment were same as those of Bakhsh *et al.* (2011) who also documented that plant growth regulators (gibberellic acid and naphthalene acetic acid) when applied at less concentration on rice crop enhanced its grain protein percentage up to maximum level.

Naphthalene acetic acid is involved in metabolic activities in plants, generates energy rich phosphate and supplies energy for physiological processes. It increases resistance against senescence, enhances growth rate, improve stimulation of nutrients from plant parts to grains which leads to more grains protein percentage; significant effect of naphthalene acetic acid were recorded when applied at panicle initiation stage in rice crop (Golam *et al.* 2012; Bray et al. 2000; Briones et al. 2002.

Grain phosphorus (mg g^{-1}):

Grain phosphorus is desired character and quality of rice is greatly influenced by grain phosphorus contents. Data presented in table 2 show that effect of naphthalene acetic acid and different phosphorus levels on grain phosphorus contents of rice was significant. However, their interactive effect was non-significant on this parameter (table 3).

Maximum grain phosphorus (2.51 mg g-1) was calculated in P3 (90 kg/ha phosphorus) treatment; grain phosphorus decreases by decreasing phosphorus dose while minimum grain phosphorus (1.34 mg g-1) was obtained by P0 (0 kg/ha phosphorus) treatment. Application of naphthalene acetic acid enhanced grain phosphorus and maximum phosphorus in grain of rice (2.18 mg g-1) was observed in NAA2 treatment, where naphthalene acetic acid was applied at the rate of 150 ppm concentration and minimum grain phosphorus (1.93 mg g-1) was noted in NAA0 treatment, where no naphthalene acetic acid was applied.

Application of more phosphorus in nutrient solution resulted in higher the content of phosphorus in flag leaves, leaves, tillers, stems and grains at maturity in rice crop; phosphorus enhances the growth of rice and increases its nutrition contents when applied with naphthalene acetic acid (Rose et al. 2008; Rose et al. 2016). Adequate availability of phosphorus to rice plant develops better root system in plants which leads to increased uptake of nutrients from soil and also enhances the nutrition and yield components (plant height, number of grains per panicle, 1000-grain weight, grain phosphorus contents, grain protein, dry matter) (Yu et al. 2016).

Table 2: ANOVA table

Source of variation	DF	PH	TPP	PP	PL	TGPP	FGPP	GW	YP	NK	CK	OK	AK	GP	P
Replication	2	0.24	0.34	0.26	0.47	14.81	25.19	0.36	0.2	0.52	0	0.01	0.13	0	0
Naphthalene acetic acid (NAA)	3	37.46	1.82**	1.66**	6.20**	137.69**	163.25**	1.40**	54.28**	127.60**	48**	70.95**	7.03**	2.82**	0.15**
Phosphorus (P)	3	613.44**	37.80**	28.97**	158.63**	3151.69**	2958.75**	59.06**	118.66**	656.35**	134.06**	81.77**	49.35**	26.96**	2.99**
NAA x P	9	0.38	0.01	0.14	0.08	2.19	1.25	0.01	0.17	1.17	0.35	0.43**	0.18**	0	0
Error	30	0.48	0.58	0.52	0.55	10.48	6.85	0.12	0.24	0.56	0.221	0.15	0.69	0.18	0

Table 3: Comparison of individual treatments' means

Treatments	PH	TPP	PP	PL	TGPP	FGPP	GW	YP	NK	CK	OK	AK	GP	P
0 mg L^{-1} (NAA_0)	125.2 C	7.8 B	7.33 B	26.15 B	81.3 C	73.3 C	27.5 C	27.79 D	65.07 D	10.97 A	10.49 A	4.76 A	7.37 D	1.93 D
100 mg L^{-1} (NAA_1)	127.0 B	8.3 AB	7.92 A	26.83 B	85.3 B	77.5 B	27.9 B	29.76 B	68.11 B	8.50 C	7.50 C	3.81 C	7.93 B	2.06 B
150 mg L^{-1} (NAA_2)	129.2 A	8.7 A	8.13 A	27.78 A	89.0 A	81.8 A	28.4 A	32.70 A	72.63 A	6.20 D	4.80 D	2.96 D	8.49 A	2.18 A
200 mg L^{-1} (NAA_3)	125.7 C	7.9 AB	7.48 B	26.40 B	82.8 BC	75.0 BC	27.8 BC	28.74 C	66.61 C	9.49 B	9.05 B	4.27 B	7.61 C	1.98 C
0 kg ha^{-1} (P_0)	118.4 D	6.3 D	6.11 D	22.48 D	66.0 D	59.3 D	25.4 D	26.13 D	59.68 D	12.79 A	10.99 A	6.28 A	6.07 D	1.34 D
30 kg ha^{-1} (P_1)	123.9 C	7.4 C	7.01 C	25.37 C	77.3 C	69.8 C	26.8 C	28.48 C	64.52 C	9.85 B	8.88 B	4.86 B	7.31 C	2.06 C
60 kg ha^{-1} (P_2)	130.2 B	8.7 B	8.00 B	28.49 B	93.2 B	83.3 B	29.1 B	30.97 B	72.10 B	7.63 C	7.13 C	2.98 C	8.50 B	2.25 B
90 kg ha^{-1} (P_3)	134.7 A	10.4 A	9.75 A	30.81 A	102.8 A	95.3 A	30.3 A	33.42 A	76.12 A	4.91 D	4.84 D	1.68 D	9.54 A	2.51 A

Results of our experiment were same as those of Jahan et al. (2012) who documented that under different phosphorus levels with naphthalene acetic acid, grain phosphorus contents were increased due to enhanced photosynthetic activity and translocation of beneficial assimilates from source (leaves) to sink (seeds). Naphthalene acetic acid enhanced the grain quality in rice when applied at low concentration (100 and 150 ppm) with different phosphorus levels as reported by Danica et al. (2003).

Results of our experiment were same as those of Bakhsh et al. (2011) who also documented that plant growth regulators (gibberellic acid and naphthalene acetic acid) when applied at less concentration on rice crop enhanced its grain phosphorus contents and grain protein percentage upto maximum level. Results of another experiment showed that exogenously application of naphthalene acetic acid (150 ppm) under different phosphorus levels enhanced the contents of phosphorus in rice seed (Wang et al. 2016).

CONCLUSION

Exogenous application of naphthalene acetic acid at 150 ppm concentration along with basal phosphorus at 90 kg ha^{-1} had quite a reasonable impact in enhancing rice yield along with improving grain quality.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

MTA and MFS conducted this research. SAH, MAR, MA and SS wrote this paper. SA, AS, MAK and SS analyzed the data. AS and SA proof read and edited the manuscript. TM helped in the revision of manuscript.

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