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Research Application Summary

# Fertilizer management for aerobic rice production system

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## Abstract

Rice is one of the favored staple foods sustaining Asian countries. Its demand increases with increasing population, however, yield of aerobic rice keeps declining when grown continuously and this is attributed to nutrient stresses and soil fertility status, particularly, soil organic matter content, which is attributed to limited practice of recycling organic residues. This field experiment was conducted during dry season from December 2014 to April 2015 at College of Agriculture, Department of Crop Science, Science City of Munoz, Nueva Ecija, Philippines to determine the effect of organic and inorganic fertilizers on growth and yield of NSIC Rc 23 under aerobic rice production system. Treatments included; 1) Control, (2) RROF (6t/ha), (3) RRIF -120-45-60 kg N, $P_2O_5$, and K2O/ha, (4)100%RRIF+ 100%RROF and (5) B5-50% RRIF+ 100%RROF. Treatments were laid out in randomized complete block design(RCBD) with three replications. Organic fertilizers at 6t/ha (convectional compost) were incorporated into the soil before planting in the respective plots, Inorganic fertilizers were split applied based on soil test results. Data Gathered included both selected crop growth and yield parameters (days to maturity, plant height at maturity (cm, total number of tillers per linear meter, number of productive tillers per linear meter, length of panicle (cm), number of filled spikelets per panicle, weight of 1000 grains (g), computed grain yield (t/ha) and straw yield (t/h). Application of inorganic fertilizers alone and in combination with organic fertilizers had significant and comparable effects on growth and yield components of NSIC Rc23 which was not the case with effects from Organic fertilizers. Application of half the recommended rate of inorganic fertilizers (120-45-60 kg N, $P_2O_5$, and $K_2O$/ha) combined with organic fertilizers at 6t/ha could be recommended for improved yield of NSIC Rc23 under aerobic rice production system.

Keywords: Chemical fertilizers, convectional compost, nutrient recycling, nutrient stresses, rice, soil fertility, yield

## Résumé

Le riz est l'un des aliments de base préférés des pays asiatiques. Sa demande augmente avec l'augmentation de la population, cependant, le rendement du riz aérobie continue de baisser lorsqu'il est cultivé en continu et cela est attribué aux stress nutritionnels et à l'état de la fertilité du sol, en particulier la teneur en matière organique du sol, qui est attribuée à la pratique limitée du recyclage des résidus organiques. Cette expérience sur le terrain a été menée pendant la saison sèche de décembre 2014 à avril 2015 au Collège d'agriculture, Département des sciences des cultures, Cité des sciences de Munoz, Nueva Ecija, Philippines pour déterminer l'effet des engrais organiques et inorganiques sur la croissance et le rendement de NSIC Rc 23 dans le cadre d'un système de production de riz aérobie. Soins inclus; 1) Témoin, (2) RROF (6t/ha), (3) RRIF -120-45-60 kg N, P2O5 et K2O/ha, (4)100%RRIF+ 100%RROF et (5) B5-50 % RRIF + 100 % RROF. Les traitements ont été disposés en blocs complets randomisés avec trois répétitions. Des engrais organiques à raison de 6 t/ha (compost conventionnel) ont été incorporés dans le sol avant la plantation dans les parcelles respectives. Les engrais inorganiques ont été répartis en fonction des résultats des analyses de sol. Les données recueillies comprenaient à la fois des paramètres de croissance et de rendement des cultures sélectionnés (jours jusqu'à maturité, hauteur de la plante à maturité (cm, nombre total de talles par mètre linéaire, nombre de talles productives par mètre linéaire, longueur de la panicule (cm), nombre d'épillets pleins par panicule, poids de 1000 grains (g), rendement en grains calculé (t/ha) et rendement en paille (t/h) L'application d'engrais inorganiques seuls et en combinaison avec des engrais organiques a eu des effets significatifs et comparables sur les composantes de croissance et de rendement des NSIC Rc23 ce qui n'était pas le cas avec les effets des engrais organiques L'application de la moitié du taux recommandé d'engrais inorganiques (120-45-60 kg N, P2O5 et K2O/ha) combiné avec des engrais organiques à 6 t/ha pourrait être recommandée pour améliorer rendement de NSIC Rc23 dans le cadre d'un système de production de riz aérobie.

Mots-clés : Engrais chimiques, compost conventionnel, recyclage des nutriments, stress nutritif, riz, fertilité du sol, rendement

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## Introduction

Rice is one of the favored staple foods sustaining Asian countries. Its demand increases with increasing population, however, yield of aerobic rice keeps declining when grown continuously (Peng *et al*., 2006). Indeed one of the current standing challenges in the universe is ensuring food security for the increasing population worldwide (Bouman, 2002). The demand for rice increases with increasing population, yet the yield of aerobic rice keeps declining when grown continuously (Peng *et al*., 2006). This decline in yields of aerobic rice is attributed to nutrient stresses and soil fertility status, particularly its soil organic matter content, which is attributed to practice of burning crop residues after harvest instead of recycling them (Singh *et al*., 2014). This condition raises the need for maintaining rice production at par with population growth rate but in an ecofriendly and more profitable way.

Sustainable rice production cannot do away with inorganic fertilizers completely, because they have significant effect on crop yield once applied appropriately. They hold nutrients that replenish soil health and ultimately improve growth components of crops. Organic fertilizers though release nutrients slowly, provide additional advantage on soil fertility by improving physical, biological and chemical soil properties (Polthanee *et al*.,2011). Combined application of organic and inorganic fertilizers in aerobic rice production enhances growth, grain yield, plant height, leaf area index and panicle length of aerobic rice (Polthanee *et al*., 2011). In our attempts to revise the way rice is grown, there is need to keep in mind the deteriorating soil health, decreasing available resources and increasing cost of production. This needs attention on boosting rice production with minimal and user friendly effects on natural resources (Gebremedhin and Tesfay, 2015).

Accordingly, this calls for boosting rice production with minimal and user friendly effects on natural resources. Aerobic rice is a new promising rice production system where rice is grown in aerobic soil supplemented with irrigation where rainfall is insufficient (Bouman, 2002). One of the most vital abiotic factors limiting rice grain yield is nutrient stress worldwide (Bouman, 2002). Among nutrients, nitrogen is the most important limiting element in rice growth thus its limitation causes reduced dry matter accumulation, prevents grain filling and increases the number of unfilled grains (Devi and Sumathi, 2011). Rice responds positively to nitrogen application, but its recovery is rather low nearly 31-40% (Cassman *et al*., 2002).

Most followed fertilizer recommendations in rice production were established under continuously submerged conditions. As such adoption of aerobic rice production may require different fertilizer management techniques (Singh *et al*., 2014). Sustainable rice production cannot do away with inorganic fertilizers since they have significant effect on crop yield once applied appropriately. They contain nutrients that replenish soil health and eventually improve growth and yield components of crops. However, farmers are facing difficulty to supply adquate amounts of fertilizers to crops due to increasing costs of mineral fertilizers (Gebremedhin and Tesfay, 2015). Similarly, organic soil amendments, though documented to improve soil quality, may not result in crop yield by their use alone due to their unavailability in large amount (Sarker *et al*., 2011).

Therefore, an integrated nutrient supply in which both organic and inorganic fertilizers are used simultaneously has been suggested as the most effective way to maintain a healthy and sustainable soil system while increasing crop productivity This improves plant growth parameters and increases rice yield (Bodruzzaman *et al*., 2010. In consideration of above observations, this study on improving aerobic rice production through fertilizer management strategies was conducted to determine the effect of organic and inorganic fertilizers when used individually or in combination on growth and yield of NSIC Rc23 under aerobic rice production system.

## Materials and Methods

**Experimental Area**. This field experiment was conducted during dry season from December 2014 to April 2015 at the College of Agriculture, Central Luzon State University, Science City of Munoz, Nueva Ecija in the Philippines.

**Soil analysis of the Experimental Area**. Prior to setting of the experiment, soil samples were collected from the experimental area, cleaned, air dried and sieved, then analyzed first using Soil Test Kit (STK) from the Department of Soil Science Laboratory, College of Agriculture, Central Luzon State University, Science City of Munoz, Nueva Ecija. However, extra soil samples from same experimental area together with the organic fertilizers were further taken for analysis at the Regional Soils Laboratory, San Fernando, Pampanga for determination of total nitrogen, organic matter, available phosphorus and potassium, soil textural class, soil pH and soil moisture content. Likewise, compost was got from the composting unit of the university, and was also analyzed before use.

**Land preparation**. Three weeks before seeding, the field was plowed and harrowed using a tractor. This gave ample time for weeds, rice straw and stubbles plowed under to decompose. To facilitate uniform irrigation and better germination, the field was leveled well. The entire area was divided into three equal blocks to represent replications. Each block was further sub divided into fifteen plots measuring 4x5 m where main treatments were assigned randomly. A total of 45 plots were used where one meter was provided between them and 1.5 meters between blocks. Each plot was separated by bunds of 0.25 m width to control irrigation water and avoid treatment contamination.

**Experimental design**. The treatments were; Control (No fertilizers), Recommended Rate of Organic fertilizers (RROF) (6t/ha), Recommended Rate of Inorganic Fertilizers (RRIF) (120-45-60 kg N, P2O5, and K2O/ha), 100%RRIF+ 100%RROF, 50% RRIF+ 100%RROF. Treatments were laid out as factorial in a randomized complete block design (RCBD) with three replications and NSIC RC 23 was the test crop. Data gathered included crop growth parameters (days to maturity, plant height at maturity (cm) and yield components (total number of tillers per linear meter, number of productive tillers per linear meter, length of panicle (cm), number of filled spikelets per panicle, weight of 1000 grains (g), computed grain and straw yield(t/h). Data generated were statistically analyzed using SIRICHAI and Comparison among means was done using DMRT at 0.05 level of significance.

**Seeding**. Seeds of NSIC RC23 were weighed, based on the seeding rate of 60kg/ha for each plot and then placed in separate plastic bags for easy sowing. Seeds were manually drilled 2 cm deep in rows 25 cm apart. A total of 120 g of seeds per plot were sown and then covered up with soil. Furrows were opened with lithao a day before sowing. After seeding, plots were flush irrigated to enhance germination.

**Fertilizer application**. Organic fertilizers were incorporated into the soil before planting in the respective plots. For treatments requiring inorganic fertilizers, application was done in splits basing on soil test results. All other agronomic practices (weeding and pest control) were done as required.

**Data analysis**. Data generated from the experiment were statistically analyzed using SIRICHAI and comparison among means was done using DMRT at 0.05 level of significance.

## Results

**Days to maturity**. Number of days to maturity of NSIC Rc23 ranged from 109-111. Plants treated with inorganic fertilizers alone, full and half inorganic fertilizers with organic fertilizer combinations matured earlier with mean of 109 days. Plants treated with sole organic fertilizers and untreated plants matured later with mean of 111 days.

Early maturity was associated with higher level of nitrogen, phosphorus and potassium. According to Crop Nutrition (http://www.cropnutrition.com/home), plants supplied with adequate nitrogen grow rapidly and produce large amounts of succulent, green foliage to full maturity due to enhanced manufacture of structural and genetic materials. Nitrogen as a component of DNA, allows cells to grow and reproduce. In comparison, application of sole organic fertilizers did not hasten early attainment of physiological maturity as combined fertilizer treatments; this was due to low nutrient content of nitrogen, phosphorus and potassium in organic fertilizers. These results suggest need for combining organic with mineral fertilizers for ideal growth conditions of plants.

## Results and Discussion



**Table 1. Growth and yield components of NSIC Rc23 as affected by fertilizer management techniques**

| Treatments Control | Days to maturity | Plant height (cm | Panicle length (cm) | Number of Filled spikelets | Total Tillers per linear meter | Number of Productive tillers | Number of Productive tillers | Computed Grain Yield (t/ha) | Straw Yield (t/h) |
|---|---|---|---|---|---|---|---|---|---|
| OF(6t/ha), | 111a | 42d | 17 | 39[d] | 261c | 207b | 207b | 1c | 3c |
| IF -120-45-60 kg (NPK) | 111a | 65c | 18 | 43[cd] | 313bc | 260b | 260b | 1c | 5c |
| 100% OF + 100%IF | 109b | 93a | 21 | 63[ab] | 396a | 369a | 369a | 3a | 9a |
| 50% IF + 100%OF | 109b | 92a | 21 | 65[a] | 376ab | 329a | 329a | 2.8ab | 7.8ab |
| | 109b | 78b | 20 | 53[bc] | 361ab | 335a | 335a | 2b | 7b |

Means sharing the same letter are not significantly different at 5% level of significance by DMRT
RRIF-Recommended rate of Inorganic Fertilizers (120-45-60kgN, $P_20_5$, $K_2O$, kg/ha)
RROF--Recommended rate of Organic Fertilizes (6 t/ha)

According to IRRI (http://www.knowledgebank.irri.org), late maturity due to nutrient stress as a result of lower rates of nutrients in applied organic fertilizers, retard manufacture of structural and genetic materials since nitrogen is a crucial component of DNA which enables cells to grow and reproduce.The present results (Table 1) indicated that plant height increased with increasing fertilizer rates. Supplying adequate fertilizers, especially nitrogen and phosphorus, hastens attainment of physiological maturity and promote root growth. According to Awan *et al*. (2011), absorbed nitrogen during vegetative and reproductive stages enhances growth and grain-filling through translocation of assimilates.

Crops grown under insufficient nutrients, especially nitrogen and phosphorus experience retarded growth, thus, delayed attainment of maturity. This was evident in untreated plots and plants treated with sole organic fertilizers. Awan *et al*. (2011) stated that growth of plants primarily depends on nitrogen availability in soil solution and its utilization by crop plants during growth and development, since nitrogen is an essential component of amino acid and related protein of the plant structure, therefore, its deficiency results in stunted growth. Early maturity in plants is advantageous since it enables timely handling of harvested crops, early land preparation for next cropping season and avoidance of insect pest attack. Late maturing varieties have longer periods of tillering than early maturing varieties.

**Plant height at maturity (cm).** Sole application of inorganic fertilizers, and full rates of inorganic and organic fertilizers in combination significantly produced tallest plants with comparable plant heights of 93 and 92 cm, respectively. These were followed by plants treated with half rate of inorganic fertilizers combined with full rate of organic fertilizers with mean of 78 cm. Application of only organic fertilizers produced plants with the height of 65 cm, whereas untreated plots produced shortest plants with mean height of 42 cm.

Basing on the study results, plant height increased with increasing level of inorganic fertilizers. This was evident in plants that received higher amount of inorganic fertilizers alone and in combination with organic fertilizers. The increase in plant height in response to combined fertilizers is due to enhanced availability of macro and micro nutrients. These results are in agreement with the findings of Mohammad *et al*. (2003) who reported that use of organic manures in combination with mineral fertilizers boosted plant growth and yield. Availability of nutrients enhanced plant height through boosting nutrient uptake from soil by cation exchange capacity. Application of nitrogen in sufficient amounts promotes leaf and stem growth. Phosphorus is critical during germination, growth of flowers, fruit, seeds and roots. Potassium promotes plant growth. Nitrogen, phosphorus and potassium deficiencies retard plant growth.

Application of organic fertilizers alone cannot substitute for the amount of nutrients present in inorganic fertilizers since they have less nutrients and take time to be mineralized before they become available for plant use. This condition was evident in plants treated with sole organic fertilizers. At the application rate, plant height was lower (65 cm) in sole organic treated plots compared to plants treated with sole inorganic fertilizers (93 cm). Half rate of inorganic fertilizers with organic fertilizer combination produced plants with lower plant height (78 cm) than full rate of inorganic fertilizers with organic fertilizer combination (93 cm). This effect was due to reduced rate of nutrients in inorganic fertilizers which could not enhance nutrient uptake by cation exchange capacity. These results suggest that application of fertilizers at recommended rates is vital for proper growth of rice plants. Siavoshi *et al*. (2011) and Saidu and Abayomi (2015) reported similar results.

**Total Number of Tillers per Linear Meter.** Application of inorganic fertilizers alone, full and half rates of inorganic fertilizers combined with organic fertilizers, significantly generated more tillers per linear meter with comparable means of 396, 376 and 361, respectively. Application of organic fertilizers alone produced comparable but superior total number of tillers (313) to those from untreated plants with mean of 261. Application of organic fertilizers significantly produced high total number of tillers which was comparable but lower to that from application of full and half rates of inorganic fertilizers combined with organic fertilizers.

According to Doberman and Frairhurst (2000), variations in tillering are associated with availability of nitrogen, phosphorus and potassium which play vital roles in plant growth, root development and tillering. Fageria (2009) noted that tillering reduces under phosphorus deficiency compared to treatments with both nitrogen and phosphorus. Phosphorus is important for plant growth, root development, tillering, early flowering and for metabolic activities, particularly in synthesis of proteins. Nutrients in organic fertilizers are lower and released slowly compared to those in inorganic fertilizers which are high and readily available for plant uptake (Panhwar *et al.,* 2011). According to IFA (2000), organic fertilizers alone are not sufficient in providing required nitrogen, phosphorus and potassium, and hence they need to be supplemented with mineral fertilizers for significant effect on tillering.

Lowest total number of tillers was recorded from untreated plants (261) and was lower than that from plants treated with sole inorganic fertilizers (313). Total number of tillers per linear meter increased with increasing levels of nitrogen, phosphorus and potassium compared with the control. In the study of Anil *et al*. (2014), higher number of tillers was recorded and attributed to higher level of nitrogen (180 kgN /ha) over 120 kgN in four split applications. In the current study, fertilizer rates used were based on Soil Test Kit (STK) recommendations; however, the results obtained suggest that the rates were not adquate to enhance tillering in aerobic rice. In addition, application of fertilizers in three splits might have not satisfied nutrient requirement of the plants in order to induce more tillering in aerobic rice. In this study, plants at their heading stage exhibited nutritional deficiency symptoms (chlorosis) and the third split of fertilizer application lowered total number of tillers.

According to the study of Devi and Sumathi (2011), application of nitrogen in four equal splits increased tillering than the usual three splits in aerobic rice (That is; one forth at basal, one forth at active tillering, one forth at panicle initiation and one forth at heading stage). These findings suggest need to update the recommended fertilizer rates currently in use in relation to new research findings.

**The Number of Productive Tillers per Linear Meter.** Plants with high tillering potential can compensate for thin stands by developing good plant densities, as they produce more tillers, they produce better yield, because each tiller under proper management, produces grain bearing panicle. Tillering is an agronomic trait for grain production and panicle number per unit area, the higher the number of tillers, the higher the panicle number (Devi and Sumathi (2011). Application of sole inorganic fertilizers, full and half rates of inorganic fertilizers with organic fertilizer combinations significantly produced more number of productive tillers with comparable means of 369, 329 and 335, respectively. Application of organic fertilizers alone significantly produced comparable number of productive tillers of 260 and 207, respectively.

Number of tillers has strong relationship with the amount of nitrogen absorbed during vegetative stage, and absorbed nitrogen at that stage, enhances tillering and panicle number. According to IRRI (http://www.knowledgebank.irri.org), number of productive tillers increase significantly with increasing levels of nitrogen, phosphorus and potassium compared to in untreated plots. This increase is attributed to more nutrient supply to plants at active tillering stage. Nitrogen, being a component of amino acids, nucleic acids, nucleotides, chlorophyll, enzymes and hormones, promotes rapid plant growth through cell division, improves grain yield and quality through higher tillering, leaf area development, grain formation and filling, as well as protein synthesis.

Sole organic fertilizers showed lesser effect compared to combined fertilizer treatments on number of productive tillers. Therefore it is not recommended for use in aerobic rice production. Inadequate supply of nitrogen, phosphorus and potassium in plants decreases number of productive tillers as evidenced in organically treated plants. The present results suggest that proper fertilizer management is a crucial factor in increasing number of productive tillers. Plants at vegetative stage absorb both basal and soil nitrogen. Plants absorb nitrogen from basal dressing before maximum tillering, thus, basal nitrogen promotes early growth and increases tiller number.

**Panicle length (cm)**. Longest panicles were recorded with application of inorganic fertilizers alone, followed by full and half inorganic fertilizers combined with organic fertilizers with comparable means of 21 cm. This was probably due to increased level of nitrogen, phosphorus and potassium. Fageria (2009) reported that nitrogen increases rice grain yield by increasing total dry matter production, panicle number and length and tillering which results in high numbers of spikelets. Application of sole organic fertilizers produced plants with comparable panicle lengths

(18,19 and 17 cm) with plants treated with half rate of inorganic fertilizers in combination with organic fertilizers (20, 20 and 19 cm). Untreated plants produced shortest panicles with a mean of 14 cm.

Heterogonous structure of the panicle has direct relationship with grain yield and panicle structure determines grain weight. Increase in panicle size due to increase in spikelet number promotes spikelet number per unit area and yield potential of the crop. Larger panicles, on the other hand, promote poor filling of grains, because grains located at secondary branches of panicle become source limited for assimilates. During grain filling stage, inefficient partitioning of assimilates and translocation from source (leaves and stems) retard development of large number of spikelets on panicle, thus causing poor starch synthesis in endosperm cells of spikelets and assimilates partitioned remain unused (Sheehy *et al*., 2001). Panicles that are too long block light interception, thus, reducing photosynthesis rate of leaves beneath the panicles and supply of assimilates to grains. Compacted panicles accommodate larger number of spikelets, however, too much compactness, lowers grain quality on secondary branches due to variations in length, width and amylose content on panicle (Wang *et al*., 2008).

**Number of filled spikelets per panicle.** Application of sole inorganic fertilizers and full rate of inorganic fertilizers combined with organic fertilizers produced significantly more number of filled spikelets per panicle with comparable means of 65 and 63, respectively. Application of half rate of inorganic fertilizers with organic fertilizer combination also produced comparable but superior number of filled spikelets per panicle (53) compared with that from application of organic fertilizers alone with mean of 43. Application of organic fertilizers alone produced fewer spikelets which was comparable to that from untreated plants with means of 43 and 39, respectively.

According to Banik *et al*. (2006), more number of filled spikelets is associated with immediate release of readily available nutrients in inorganic fertilizers during panicle initiation stage which greatly improves supply of assimilates to grains. Toa *et al*. (2006) stated that absorbed nitrogen during reproductive and ripening stages promotes panicle development which is reflected in increased spikelet number. In addition, nitrogen stimulates absorption of nutrients and assimilation; this is reflected in number filled grains. Grain filling is the process of starch accumulation and depends on carbon from current assimilates and assimilates from vegetative tissues. Mohammad *et al*. (2003) observed that application of combined fertilizer treatments, has additional advantage in increasing number of filled spikelets as compared with application of organic fertilizers alone. This is associated to increase in nutrient use efficiency. Higher number of spikelets is an indicator of high yielding rice.

**Total number of spikelets per panicle.** Application of sole inorganic fertilizers, full rate of inorganic in combination with organic fertilizers produced significantly highest total number of spikelets per panicle with comparable means of 76 and 77, respectively. Plants treated with organic fertilizers alone produced comparable total number of spikelets with that from half rate of inorganic fertilizers combined with organic fertilizers per panicle with the means of 60 and 67, respectively. However, results were inferior to the number from combined fertilizer treatment. Untreated plants had significantly fewer total number of spikelets even to that from organic fertilizer treatment, with means of 58 and 60, respectively.

The highest total number of spikelets with inorganic and inorganic plus organic fertilizer is attributed to availability of nitrogen, phosphorus and potassium at panicle initiation stage. Uddin (2003) reported that applying sufficient amount of nitrogen, phosphorus and potassium in rice improves total number of spikelets per panicle as a result of greater assimilation of photosynthates. Number of differentiated spikelets is proportional to plant uptake and concentration of nitrogen at panicle initiation.

Fageria (2009) pointed out that rice plants need nitrogen throughout their vegetative stage, but in particular, during tillering and panicle initiation stages. During vegetative stage, nitrogen is first assimilated in leaves, then migrates to panicles and grains at maturity, where 75% of assimilated nitrogen is in grains. Nitrogen contributes to sink size by decreasing number of degenerated spikelets and increasing size of hull. The role of nitrogen in grain filling is to increase leaf weight and nitrogen content in leaves, thus enhancing photosynthetic capacity and promoting carbohydrate accumulation in culms and leaf sheaths. Top dressing of nitrogen at grain filling stage is recommended (Ying *et al*., 1998). The lower total number of spikelets per panicle was therefore likely due to lower rates of nitrogen, phosphorus and potassium in organic fertilizers which affected spikelet number due to reduced assimilation of photosynthates (Uddin, 2003).

**Weight of 1000 grains (g)**. Application of inorganic fertilizers alone, full and half rates of inorganic fertilizers combined with organic fertilizers produced significantly heavier 1000 grain weight with comparable means of 22, 21 and 21 grams, respectively. Application of organic fertilizers alone produced plants with 1000 grain weight of 21 g, which was comparable to that from application of inorganic fertilizers alone, full and half rates of inorganic fertilizers combined with organic fertilizers with means of 22, 21 and 21g, respectively. The recorded heavier 1000 grain weight was probably associated with higher solubility of phosphorus and faster release of nutrients from inorganic fertilizers. Singh *et al*. (2007) stated that nitrogen is vital for grain filling purposes. Increase in grain weight at higher nitrogen rates is due to increase in chlorophyll content of leaves which results into higher photosynthetic rate and consequently plenty of photosynthates available during grain development. According to Mohammad *et al*. (2003), application of inorganic fertilizers at panicle initiation or early booting stage enables plants to produce more and heavier grains per panicle. Yoshida (1981) stated that weight of 1000 grains is a stable genetic character because size of grain is controlled by size of the hull, the bigger the size of the hull, the bigger the size of the grain. Greater grain weight contributes to higher grain yield.

**Grain yield (t/ha).** Application of inorganic fertilizers alone, and full rates of inorganic fertilizers with organic fertilizer combination, produced the highest computed grain yield with comparable means of 3 and 2.8 t/ha, respectively. Application of half rate of inorganic fertilizers with organic fertilizer combination produced computed grain yield of 2 t/ha.

Application of organic fertilizers alone and untreated plots produced significantly lowest grain yield with comparable means of 1 t/ha. Usman *et al*. (2000) stated that combined application of nutrients decreases number of abortive kernels per panicle. Organic manures, as discussed earlier, increase fertilizer use efficiency and improve physical and chemical properties of soil, hence, making better utilization of nutrients towards increased yield. This implies that reduction from recommended rates of nitrogen, phosphorus and potassium lowers grain yield.

Mohammad *et al*. (2003) revealed that in plant nutrition, inorganic fertilizers combine with compounds produced by carbohydrates metabolism to form amino acids and proteins which are involved in plant development and yield attributes. They further stated that at early vegetative and panicle initiation stages, nitrogen, phosphorus and potassium are needed most for promotion of tillering which leads to higher yield. Application of inorganic fertilizers at panicle initiation or early booting stage enables a plant to produce more heavier grains per panicle.

In this study, nutrient content in organic fertilizers was too low to satisfy nutrient demand of crops. The above explains why plants that received combined fertilizer treatments (organic plus inorganic) gave higher yield than those with sole organic fertilizer treatments, thus, reflecting the need for supplemental chemical fertilizers for significant effect on yield. Banik *et al.* (2006) said that combination of organic with inorganic fertilizers increased fertilizer use efficiency and improved physical and chemical properties of soil, thus, leading to increased yield. Grain yield increases with increasing availability of nutrients as evidenced from application of inorganic fertilizers compared to in the untreated plots. Adequate supply of nitrogen, phosphorus and potassium is recommended for uptake of other nutrients, hence, meets nutrient demand of plants at critical stages of development, thus, increasing grain weight (IFA, 2000). Maximum rice productivity therefore appears to depend on split application of inorganic fertilizers for efficient mobilization of reserved and current photosynthates for grain filling, increasing nutrient recovery and uptake, thus, increasing yield (Cheema and Usma, 2001). In this study, application of inorganic fertilizers at rates 120-45-60 kgN, $P_2O_5$, $K_2O$/ha in three splits did not satisfy nutrient demand of plants and this was reflected by nutrition deficiency symptoms in plants after receiving the pre-determined fertilizer rates.

Results of lower grain yield in this study correspond well with Haefele *et al.* (2013) recommendation of the need for higher nitrogen rates in dry season of up to 150 kgN/ha for aerobic rice. Similarly, Singh *et al.* (2007) noted that rice grain yield increases significantly as nitrogen rates are increased up to 160 kgN/ha irrespective of establishment methods. The current finding show that aerobic rice requires more nitrogen, phosphorus and potassium in dry season than the rate of 120 kg N used in the study. According to Singh *et al.* (2014), application of 175 kg N resulted in higher growth, yield attributes and grain yield compared to application of 100 and 120 kg N/ha, indicating that direct seeded rice requires more nitrogen than transplanted rice.

**Straw yield (t/ha).** Application of inorganic fertilizers alone, full and half rates of inorganic fertilizers combined with organic fertilizers significantly produced highest straw yield with comparable means of 9, 7, 8 and 7 t/ha, respectively. Application of organic fertilizers alone produced lowest straw yield which was comparable with that from untreated plants with mean yields of 3 and 5 t/ha, respectively.

Higher straw yield was likely due to the ncreased levels of nitrogen, phosphorus and potassium which were immediately released for plant absorption compared to in the control. According to Sekhar *et al.* (2014), nutrients from inorganic fertilizers are released immediately after application, thus meeting nutrition demand of crops, while nutrients from organic fertilizers are released gradually but steadily, thus, ensuring continuous supply of nutrients throughout growth period.

Singh *et al.* (2014) indicated that in plant nutrition, effect of nitrogen is attributed to the fact that nitrogen is a constituent of nucleotides, proteins, chlorophyll and enzymes participating in metabolic processes which have direct effect on vegetative and reproductive phases of crop growth. In this study, grain yield was lower compared to straw yield, implying that plants were not efficient in converting absorbed nutrients and products of photosynthesis into grain yield, and as such assimilates were not translocated efficiently to sink.

## Conclusion

Based on the results of their study, it can be concluded that application of inorganic fertilizers alone and in combination with organic fertilizers significantly influenced the growth and yield components of NSIC Rc23 such as days to maturity, plant height at maturity (cm) and yield components (total number of tillers per linear meter, number of productive tillers per linear meter, length of panicle (cm), number of filled spikelets per panicle, weight of 1000 grains (g), computed grain yield (t/ha) and straw yield(t/h). Further, sole inorganic fertilizers application had comparable effects but superior influence compared to those of fertilizer combination treatments. Therefore, application of half the recommended rate of inorganic fertilizers combined with organic fertilizers could still enhance growth and yield attributes of NSIC Rc23, thus, saving farmers from high costs of inorganic fertilizers alone under aerobic rice production system.

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