International Journal of Plant & Soil Science

31(6): 1-8, 2019; Article no.IJPSS.54117
ISSN: 2320-7035

Effects of Nitrogen Rates on Morphological Development of Upland Rice Varieties in Mwea, Kirinyaga County, Kenya

Sammy Kingei Kagito[1*] and Esther W. Gikonyoi[1]

[1]Kenya Agricultural and Livestock Research Organization, Kenya.

Authors' contributions

This work was carried out in collaboration between both authors. Author SKK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author EWG managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2019/v31i630226
Editor(s):
(1) Dr. Omer Kilic, Bingol University, Turkey.
Reviewers:
(1) Chemutai Rosline, Bukalasa Agricultural College, Uganda.
(2) Benjawan Chutichudet, Mahasarakham University, Thailand.
Complete Peer review History: http://www.sdiarticle4.com/review-history/54117

Original Research Article

Received 28 November 2019
Accepted 02 February 2020
Published 08 February 2020

ABSTRACT

Rice is the third most important cereal in consumption after maize and wheat in Kenya. It has been grown as a commercial food crop under irrigated and rain fed ecologies. Low soil Nitrogen (N) fertility is a major constraint to upland rice production in smallholder farmers mostly under rain fed agriculture. This study evaluated the morphological development of upland rice varieties as influenced by different N fertilizer treatments. A field study was carried out at the Kenya Agricultural and Livestock Research Organization experimental farm in Kirinyaga County for two seasons. The experiment was laid down as a randomized complete block design (RCBD) in split-plot arrangement in three replications. The main plot factors were the five upland rice genotypes, MWUR1, MWUR4, NERICA4, NERICA10 and IRAT109, while the subplots factors were the four N rates, 0, 26, 52 and 78 kg N ha^{-1}. In addition calcium ammonium nitrate (26% N) was top-dressed in two equal splits at 21 and 45 days after sowing. Data on plant growth parameters was collected at fortnight interval. The analysis of variance revealed significant ($p < 0.05$) variation on plant height and tiller numbers due to N rates. However, there was no significant variation in plant height and tiller numbers due to variety. In addition, shoot and root dry weight and leaf area were significantly

**Corresponding author: E-mail: samkagito@gmail.com;*

different due to variety and N rates in both seasons. Finally root dry weight was not significantly different due to variety and N-rates in the two seasons. The current study has shown that increase in nitrogen level lead to significant increase in plant height, tiller numbers, shoot dry weight and root dry weight. The study recommends the use of N fertilizers for rice cultivation to increase N supply in the soil.

Keywords: Rice; varieties; nitrogen levels; growth parameters.

1. INTRODUCTION

Rice is an annual crop belonging to the family of grass [1] and is consumed worldwide by more than half of the world population [2]. It ranks third in area after wheat and maize and second both in production and productivity after maize worldwide [3]. Over 90% of the world's total rice crop is produced in South and East Asia. In area and production, China is the leading country in the world [4]. In Kenya it was introduced in1907 and is currently the third most important cereal crop after maize and wheat [5]. It has traditionally been grown by small-scale farmers as a commercial food crop within irrigation schemes, rain fed lowlands and upland ecologies. Among the lowland areas where rice is produced in Kenya is Mwea, but mainly through irrigation, particularly under flooding irrigation method [6]. Although, rice plays a significant role as a food security crop and in uplifting social-economic status of people and the country as a whole, the National rice consumption is estimated at 530,000 metric tons, compared to an annual production of about 129,000 metric tons [7]. This rice production meets only 26.8% of total domestic demand and is expected to rise with increasing population and change in eating habits [8]. For instance, rice consumption is increasing at a rate of 12% annually and therefore its production must increase to ensure self sufficiency. In the meantime, the deficit is met through imports valued at over KES 9 billion [7].

Nitrogen is an important to plants and is the most frequently deficient of all nutrients in agricultural production systems [9]. Plants need nitrogen in fairly larger amounts than other elements [10]. Nitrogen is needed and absorbed by the rice plant at almost all the growth stages thus it's important in rice plant growth and yield. It's absorbed by the plants as nitrate (NO_3^-) and ammonium (NH_4^+) ions. It plays a significant role in crop production such that it has structural and functional role in relation to plant growth and development [11,12,13]. It is an important component of numerous organic compounds such as amino acids, nucleic acids and proteins [14]. Photosynthetic organs contain a lot of nitrogen and synthesis of enzymes highly requires nitrogen. The low input use and low availability of soil nitrogen constrain rice productivity [15]. Actually, Opukiri [16] observed that nitrogen is the most limiting plant nutrient for rice production in the tropics. This is because soil applied N is often lost through various transformation pathways such as volatilization, denitrification and leaching [17].

Therefore, the major challenge facing farmers especially those practicing small scale farming in Kenya is that most of the farms have low soil fertility and poor soil management [18]. The situation is exacerbated by the fact that few farmers can afford the chemical fertilizers since their costs are very high and continue to increase steadily due to escalating oil prices. According to Otsuka [19] the level of nutrient application by smallholder's farmers is low mainly due to the high costs of artificial fertilizers. This challenge has led to dwindling rice yields as a result of continuous production in the same fields without soil replenishment despite the massive soil depletion and degradation. Besides, for many years, wetland rice paddies in the study area have depended entirely on nutrients supplied from the soil and flood/irrigation water which are now becoming increasingly inadequate to sustain good growth and yield in a continuous cropping system. It on this basis that this study was carried out to determine the effects of nitrogen rates on morphological development of upland rice varieties in Mwea, Kirinyaga County, Kenya.

2. MATERIALS AND METHODS

2.1 Study Area Description

The study was conducted at the Kenya Agricultural and Livestock Research Organization (KALRO-Mwea) Kirogo farm in Kirinyaga County. Kirogo farm is situated at latitude 0°37'S and longitude 37°20' E at an elevation of 1159 m above sea level. The area receives an average rainfall of about 850 mm per annum which is divided into long rains (March to June with an average of 450 mm) and short rains (mid October to December with an average of 350 mm).The rain is characterized by uneven distribution in total amount, time and space. The area temperature ranges between 15.4°C and 29.5°C with a mean of about 22°C. The soils in Kirogo farm experimental site are Nitosol soils, which are deep, well drained dusky-red to dark reddish-brown, friable clay with low fertility. The study area is within the Agro Ecological Zone Lower Medium 3 (AEZ LM3) and experiences a bimodal pattern of rainfall.

2.2 Experiment Design and Layout

The study had twenty treatments which were randomly assigned in the experimental plots. The experiment laid out in split plot design, arranged in randomized complete block design (RCBD) in three replicates. The main plot factors were the five upland rice genotypes, MWUR1, MWUR4, NERICA4, NERICA10 and IRAT109, while the subplots factors were the four N rates: 0, 26, 52 and 78 kgN ha^{-1} applied in form of (CAN). The study was carried out in the field and had a total of sixty experimental plots. Each plot measured 2 m × 1.5 m and each plot was separated from one another by a 1 m path. Initial soil was sampled from the experimental field using the zig zag method for analysis. Later, Sunflower seeds were planted for one season in the plots before the commencement of the study. This is because Sunflower plant is deep rooted and has the ability to extracts soil nitrogen in large quantities. This was done to deplete soil nitrogen, since Krishna [20] reported that Sunflowers seeds are sinks of plant nitrogen which is accumulated in their endosperm. After Sunflower harvesting, another soil sampling was done for analysis.

2.3 Crop Husbandry

The rice seeds were directly sowed in rows at a spacing of 20 cm by 15 cm by dibbling [21]. Each plot had five rows. Fertilizer (CAN) treatments were randomized in each block. Zinc, a micro-nutrient was blanket applied as zinc sulphate at a rate of 25 kg $ZnSo_4$ /ha [22]. Four nitrogen treatments, 0 kgN ha^{-1} (control), 26 kgN ha^{-1} (low rate), 52 kgN ha^{-1} (standard rate) and 78 kgN ha^{-1} (high rate) were used. The routine agronomical practices of weeding, pest control and periodic irrigation were applied. The fertilizer treatments were applied to the soil in two equal splits with the first split being applied at tillering stage, 21 days after sowing (DAS) while the second split was applied after 45 days at panicle initiation stage. Nets were installed across the experimental field just before heading stage to prevent rice grains from bird damage.

2.4 Data Collection and Analysis

Data collection commenced one month after sowing and continued after every two week until the crop attained its full maturity. The growth parameters scored were plant height (measured using a metre ruler); number of tillers (by counting); shoot and root dry weights (using a weighing balance) and leaf area (length and width of the top, middle and lower marked leaves, there after the average of the three leaves was calculated). The data was recorded on a designed data sheet and later subjected to analysis of variance (ANOVA) using general linear model [GLM] of SAS system for windows (SAS institute 1998, version 8). Significant means were separated using least significant difference (LSD) at 5% level for comparing nitrogen level means [23].

3. RESULTS AND DISCUSSION

Growth of upland rice variety was ascribed by plant height, tiller number, shoot and root dry weights and leaf area.

3.1 Plant Height and Tiller per Plant

At the end of the experiment, the results from the study showed that the plant height and tiller numbers did not differ significantly ($P \leq 0.05$) according to variety, although MWUR1 exhibited higher plant height in both seasons with IRAT recording the lowest values. Further NERICA 1 exhibited higher tiller numbers (8.08) in season one while NERICA 10 gave the highest tiller number (12.56) in season two (Table 1). The lack of significance response as influenced by varieties may be due to the fact that there were no much genetic differences between the varieties.

The plant height and number of tiller were significantly different ($P \leq 0.05$) from each other as influenced by N rates in the two seasons. N rate (78 kgN Ha^{-1}) gave both the highest plant height and tiller numbers in both seasons. In light of this, the interaction between variety and nitrogen levels was not significantly different in both seasons (Table 1). Plant height is varietal characteristics and is genetic constituent of the cultivars. The varieties did not differ in this study and we speculate it could be due the effects of the environment. [24,25,26] stated that the variation in genetic makeup of a plant is influenced by heredity and environmental conditions.

In the study, plant height and tiller numbers were significantly affected by different nitrogen levels ($p \leq 0.05$). Nitrogen is closely related to plant growth and development and affects cell regulation and metabolism. It is also a major contributor to crop growth, size and total dry matter production. In particular, growth promoting effect of N on plant can be explained on the basis of the fact that N supply increases the number and size of meristematic cells which leads to formation of new shoots [27]. In addition, the number of tillers can be increased by applying nitrogen fertilizer [28]. It also enhances the development of tillers [29]. Rajput [30] proved that nitrogen was responsible for the increase in the number of tillers per hill due to its important role in the division of plant cells. Similary Yoshida [31] stated that as the amount of nitrogen absorbed by the crop increased, there was an increase in the number of tillers per square meter.

According to Jan [32] plant height reveals the overall vegetative growth of rice crop in response to nitrogen. Also, the increase in height with increasing nitrogen levels confirms the finding of [33] who observed that there were significant increases in plant height with increasing N- levels in rice. The high plant height due to increase in nitrogen rate was possibly due to enhanced rate of translocation on nitrogen from culm to leaves, leading to production of photosynthates which enhance translocation of nutrients for developing panicles.

3.2 Shoot Dry Weight and Root Dry Weight

Shoot dry weights were significantly different at $P \leq 0.05$ due to varieties in seasons on only as shown in (Table 2), with the highest (30.30 g) shoot dry weight was recorded in variety MWUR 1. We speculate that MWUR 1 variety produced highest shoot dry weight than the other varieties since it initially grew very fast resulting in more shoot biomass. There was significant variation ($p<0.05$) in shoot dry weight and root dry weight due to N levels in both seasons. Though in terms of shoot dry weight N rate (52 kgN ha^{-1}) recorded the highest value (29.85 g) in season one, while N rate (78 kgN ha^{-1}) had the highest value (24.95 g). In terms of root dry weight, significant variation at $p<0.05$ was only recorded in season one with N rates resulting in high root dry weight than the control (Table 2).

In both seasons N rates gave increased shoot and dry weights as compared to the control. The increase in shoot and root dry weight in response to application of N fertilizers is probably due to enhanced availability of nitrogen which enhanced more leaf area resulting in higher photo assimilates and thereby resulting in more dry matter accumulation. These results are supported by the findings of Mandal et al. [34].

Table 1. Plant height and tiller number per plant as influenced by varieties and N-rates for the two seasons

	Season 1		Season 2	
	Plant height (cm)	**Tiller numbers**	**Plant height (cm)**	**Tiller numbers**
Varieties				
MWUR1	79.11^a	7.98^a	97.12^a	11.64^a
MWUR4	74.14^a	7.69^a	93.03^a	11.61^a
NERICA4	67.03^a	8.08^a	90.50^a	11.42^a
NERICA 10	71.14^a	7.28^a	82.56^a	12.56^a
IRAT	66.53^a	7.72^a	80.61^a	12.64^a
$LSD_{0.05}$	9.63	1.86	11.75	2.70
NR ($kgha^{-1}$)				
Control	55.76^c	5.75^c	74.18^c	8.58^c
26	70.73^b	7.61^b	84.59^b	11.78^b
52	78.53^a	8.15^{ab}	92.42^b	13.24^{ab}
78	81.33^a	9.49^a	103.87^a	14.29^a
$LSD_{0.05}$	5.21	1.30	7.84	1.77
VXNR	NS	NS	NS	NS

V: variety, NR: Nitrogen rates, NS: No significance, VXNR: Varieties interacting with Nitrogen rates, means followed by the same superscript letters are not significantly different at 5% probability level

Table 2. Shoot dry weight and root dry weight as influenced by varieties and N-rates for the two seasons

	Season 1		Season 2	
	SDW (g)	RDW (g)	SDW (g)	RDW (g)
Varieties				
MWUR1	19.73^{a}	1.25^{a}	30.30^{a}	2.82^{a}
MWUR4	18.20^{a}	1.26^{a}	24.87^{ab}	2.87^{a}
NERICA 4	16.27^{a}	1.41^{a}	24.87^{ab}	2.97^{a}
NERICA10	14.18^{a}	1.21^{a}	19.70^{b}	2.82^{a}
IRAT	12.46^{a}	1.29^{a}	18.38^{b}	2.89^{a}
$LSD_{0.05}$	6.62	0.38	6.85	0.39
NR (kg ha^{-1})				
Control	6.52^{c}	0.85^{a}	16.51^{c}	2.56^{b}
26	14.69^{b}	1.25^{a}	21.55^{bc}	2.88^{a}
52	18.53^{b}	1.42^{a}	29.85^{a}	2.91^{a}
78	24.95^{a}	1.60^{a}	26.49^{ab}	3.14^{a}
$LSD_{0.05}$	3.46	0.27	5.69	0.31
VXNR	NS	NS	NS	NS

V: variety, NR: Nitrogen rates, NS: No significance, VXNR: Varieties interacting with Nitrogen rates, means followed by the same superscript letters are not significantly different at 5% probability level

Table 3. Leaf area at maximum tillering and panicle initiation stages as influenced by varieties and N-rates for the two seasons

	Season 1		Season 2	
	LAMT	LAPI	LAMT	LAPI
Varieties				
MWUR1	31.19^{a}	34.61^{a}	50.10^{a}	60.09^{a}
MWUR4	29.25^{ab}	32.55^{a}	45.23^{ab}	53.52^{ab}
NERICA4	29.80^{ab}	33.02^{a}	41.46^{ab}	45.44^{ab}
NERICA 10	26.26^{b}	29.40^{a}	33.88^{b}	40.69^{b}
IRAT	34.52^{a}	37.39^{a}	51.98^{a}	57.36^{a}
$LSD_{0.05}$	5.14	6.85	8.06	10.73
NR (kg ha^{-1})				
Control	26.14^{b}	28.34^{b}	34.06^{b}	46.22^{b}
26	28.21^{b}	30.17^{b}	44.38^{a}	51.22^{ab}
52	31.49^{ab}	34.20^{ab}	46.72^{a}	61.66^{a}
78	34.99^{a}	40.87^{a}	52.97^{a}	46.57^{b}
$LSD_{0.05}$	4.28	5.21	6.95	9.94
VXNR	NS	NS	NS	NS

LAMT: leaf area at maximum tillering, LAPI: leaf area at panicle initiation, V: variety, NR: Nitrogen rates, NS: No significance, Varieties interacting with Nitrogen rates, means followed by the same superscript letters are not significantly different at 5% probability level

Also, this is because the good supply of nitrogen to plants stimulates root growth development as well as uptake of other nutrients [35]. Reports indicate that in rice plants, roots plays a significant role in absorption of nitrogen with root density and distribution in the soil being the major determinant [36]. Root characteristics such as root length density and root weight have been identified as important factors since nitrogen uptake is determined by root mass and nitrogen uptake per root volume [37]. Interactions between variety and nitrogen rates were not significantly different (Table 2).

3.3 Leaf Area at Maximum Tillering and Panicle Initiation Stages

Data presented in (Table 3) showed that varieties and nitrogen fertilization rates exerted significant effect at P≤0.05 on leaf area of upland rice variety. The leaf area was high during panicle initiation than tillering stage in season one and the trend was the same in season two. The highest leaf area (60.09 cm^2) was recorded in MWUR 1 variety in season two.

In terms of N rates leaf area of rice increased over time from tillering stages to panicle initiation stages by gradual elevation of nitrogen fertilizer in season one (Table 3). However in season two during panicle initiation stages leaf area increased up to 61.66 cm^2 in N rate 52 $kgha^{-1}$ thereafter it showed a falling trend (Table 3). Interactions between varieties and N rates revealed that there was no significance difference. In case of any plant, leaves are important organs which have an active role in photosynthesis. According to Tari [38] to achieve high yield, maximization of leaf area is an important factor of the crop. Varieties leaf area differed significantly due to variety. This indicates that the five varieties out performed each other. We speculate that NERICA 10 having the lowest leaf area for the two seasons captured less solar radiation resulting in low production of carbohydrates. Furthermore, the increasing trend of leaf area at higher nitrogen levels (Table 3) can be attributed to the positive effect of nitrogen on both leaf development and leaf area duration of the varieties [39,40]. Actually N rate has a profound effect on leaf area development [41]. According to Huang [42] it because N application increases the levels of cytokinin which affects cell wall extensibility. Also, the increase in leaf size due to enough nutrition was expected in terms of possible increase in nutrient absorption capacity of the varieties through better root development and increased translocation of carbohydrates from source to growing grains [38]. It is therefore, logical to speculate that N was involved directly or indirectly in the enlargement and division of new cells and production of tissues which in turn were responsible for increase in growth characteristics particularly leaf area of the upland rice variety. Generally season two elicited higher values than season one (Tables 1, 2 and 3). This could have been so due to supplementary irrigation that was initiated as a result of higher temperatures experienced in the season.

4. CONCLUSION

The current study has shown that increase in nitrogen level lead to significant increase in plant height, tiller numbers, shoot and root dry weight and leaf area. However, its excessive application in rice production is not beneficial from the standpoint of agronomy and environment, since nitrogen fertilizer based pollution is becoming a serious issue for many regions where agriculture is concentrated. Therefore, taking the finding of the present study into consideration, it may be tentatively concluded that farmers in the study region should apply N at 52 kg ha^{-1} rate to improve on upland rice production. Since high N results in rice diseases, pests and lodging.

ACKNOWLEDGEMENT

The authors thank KALRO for their facilities. The corresponding author wishes his heartfelt gratitude to his wife, Jane Nyambura for her encouragement.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bandyopadhay S, Roy CN. Rice processing technology. IBTT Publishing Co. PVT. Id, 66 Japath, New Delhi, India; 1992.
2. Tao LX, Wang X, Xuang XL, Min SK, Cheng SH. Effects of soil moisture content on physiological activity of rice root system during grain-filling stage. China National Rice Research Institute, Hangzou, China, Scientia-Agricultura-Sinica. 2004;37 (11):1616-1620.
3. FAOSTAT (Food and Agriculture Organization Statistical Databases, United Nations). World food and agriculture. Food and Agriculture of the United Nations, Rome, Italy; 2012.
4. EUCORD (European Cooperative for Rural Development). Rice sector development in East Africa a desk study prepared for common fund for commodities. Brusseles; 2012.
5. GOK. National Rice development strategic plan (2008-2018). Ministry of Agriculture; 2009.
6. Ministry of Water and Irrigation. Kenya Natural Resources Management Project-Irrigation and Drainage Sector Institutional Reform Consultancy Final Study Report. World Bank; 2009.
7. Government of Kenya. Ministry of Livestock Development Annual Report; Government Printer, Nairobi, Kenya; 2012.
8. FAO. Selected indicators of food and agricultural development in the Asia-Pacific Region, 1986-96; FAO-RAP Publication

No. 1997/23. Regional Office for the Asia and the Pacific, FAO Bangkok, Thailand. 1997;206.
9. Balkos KD, Britto DT, Kronzuker HJ. Optimization of ammonium acquisition and metabolism by potassium in rice. Plant Cell Environment. 2010;33: 23-34.
10. Wang L, Xu YC, Schjoerring JK. Seasonal variation in ammonia compensation point and nitrogen pools in beech leaves (*Fagus sylvatica*), Plant Soil. 2011;343:51–66.
11. MengelK, Kirkby EA. Principles of plant nutrition. International potash Institute publ., Switzerland; 1987.
12. Epstein E, Bloom AJ. Mineral nutrition of plants: Principles and prospective. Second Ed. Sinauer Association, Sunderland, Massachusetts; 2005.
13. Taiz L, Zeiger E. Plant Physiology, 5th edn. Sinauer Associates Inc. Publishers, Massachusetts; 2010.
14. Epstein EA. Aquisição de nitrogênio. In: Nutrição mineral de plantas: Princípios e perspectivas. Malavolta E (Trad.) Rio de Janeiro, Livros Técnicos e Científicos, São Paulo, EDUSP. 1975;213-234.
15. Mghase JJ, Shiwachi H, Nakasone K, Takahashi H. Agronomic and socio-economic constraints to high yield of upland rice in Tanzania. Africa Journal of Agriculture Research. 2010;5:150-158.
16. Opukiri SB, Zuofa K, Douglass PC. The influence of urea fertilization on yield of rice on acid soil in Rivers State. Nig. J. of Crop/Soil Science and Forestry. 2011;(1): 42-45.
17. De Datta SK. Nitrogen transformation processes in relation to improved cultural practices for lowland rice. Plant and Soil. 1997;100:47-69.
18. Muzari W, Gatsi W, Muvhunzi, S. The impacts of technology adoption on smallholder agricultural productivity in Sub-Saharan Africa: A review. Journal of Sustainable Development. 2012;5(8): 69-70.
19. Otsuka K, Kalirajan K. Rice Green Revolution in Asia and its transferability to Africa. Dev. Econ. 2006;44:107-122.
20. Krishna KR. Agroecosystem: Nutrient dynamics, ecology and productivity. Brown Walker Press Inc, Boca Raton, Florida, USA. 2010;553.
21. MOA. Guideline for growing New Rice for Africa (NERICA); 2012.
22. Africa Rice Center (Africa rice); 2002. Available:www.africarice.org/publications/com/nec
23. Steel RGD, Torrie JH, DA. Dickey. principles and procedures of statistics: A biometrical approach. 3rd Ed. McGraw Hill Book Co. Inc. New York. 1997;400-428.
24. Mohammed TW Deva, Ahmad Z. Genetic variability of different plant and yield characters in rice. Sarhad Journal of Agriculture. 2002;18:207-210.
25. Chamley SG, Islam N, Hoshain S, Rabbani MG, Kader MA, Salam MA. Effect of variety and nitrogen rate on the yield performance of boro rice. Progressive Agriculture. 2015;26(1):6-14.
26. Chowdhury MJU, Sarker AU, Sarker MAR, Kashem MA. Effect of variety and number of seedlings per hill on the yield and components on late transplanted aman rice. Bangladesh Journal of Agricultural Sciences.1993;20(2):311-316.
27. Maske NS, Borkar SL, Rajgire HJ. Effects of nitrogen levels on growth, yield and grain quality of rice. Journal of Soils and Crops. 1997;7:83-86.
28. Liu Y, Ghen Jian F. Methods on identification and screening of rice genotypes with high nitrogen efficiency. Rice Science. 2011;18(2):130-133.
29. Sakakibara H, Takei K, Hirose N. Interactions between nitrogen and cytokinin in the regulation of metabolism and development. Trends in Plant Science. 2006;11:440-448.
30. Rajput MKK, Ansari AH, Mehdi S, Hussain AM. Effect of N and P fertilizers alone and in combination with organic matter on the growth and yield of Toria. Sarhad Journal of Agricultural Research. 1998;4:3-6.
31. Yoshida S, Cock JH, Parao FT. Physiological aspects of high yield. International Rice Research Institute. Rice Breeding. 1972;455-469.
32. Jan MT, Shah M, Khan S. Types of N-fertilizer rate and timing effect on wheat production. Journal of Agriculture. 1997;18 (4):405-410.
33. Ethan S, Odunze A, Abu S, Iwuafor E. Effect of water management and nitrogen rates on iron concentration and yield in lowland rice. Agriculture and Biology Journal of North America. 2011;2: 622–629.
34. Mandal NN, Chaudhry PP, Sinha, D. Nitrogen, phosphorus and potash uptake

of wheat (var. Sonalika). Env. and Eco. (Field Crop Abst.). 1992;46(1):30.
35. Brady NC, Weil RR. The nature and properties of soils. 13th Ed. Person education Ltd, USA. 2002;621.
36. Youngdahl LJ, Pacheco R, Street JJ. The kinetics of ammonia and nitrate uptake by young rice plant. Plant and Soil. 1982;9: 225-232.
37. Shimono H, Bunce JA. Acclimation of nitrogen uptake capacity of rice to elevated atmospheric CO_2 concentration. Annals of Botany. 2009;103: 87–94.
38. Tari DB, Gazanchian A, Pirdashti HA, Nasiri M. Flag leaf morphophysiological response to different agronomical treatments in a promising line of rice (*Oryza sativa* L.). American-Eurasian Journal of Agricultural and Environmental Science. 2009;5:403-408.
39. Shokri S, Siadat SA, Fathi G, Maadi B, Gilani A, Mashhadi AA. Effect of nitrogen rates on dry matter remobilization of three rice cultivars. International Journal of Agricultural Research. 2009;4:213-217.
40. Kumar GB, Gangwas RK. Importance of leaf area index and forest type when estimating photosynthesis in boreal forests. Remote Sensing of Environment. 1993;43:303-314.
41. Kumura A. Physiology of high yielding rice plants from the view point of dry matter production and its partitioning. In science of the rice plant, physiology, Eds. Matsuo et al. Food and Agriculture Policy Research Center, Tokyo. 1995;2:704-736.
42. Huang M, Zou YB, Jiang P, Bing XIA, Md I, Ao HJ. Relationship between grain yield and yield components in super hybrid rice. Agricultural Sciences in China. 2011;10: 1537-1544.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/54117