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GROWTH, YIELD AND NUTRIENT UPTAKE OF DIRECT SEEDED RICE AS AFFECTED BY NITROGEN AND PHOSPHORUS APPLICATION

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BY

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Chairman: Assoc. Prof. Dr. Surjit Singh

Faculty: Faculty of Agriculture

Pot and field trials using rice varieties IR 72, MR 84 and MR 142 were conducted to determine the effects of N and P rate on growth, yield, yield components and nutrient uptake of direct seeded rice. The experiments were carried out in a Randomised Complete Block design with four replicates, for the pot trial and three replicates for the field trial.

Results from the pot trial indicated that higher N rate increased plant height, tiller number, total dry matter (TDM) and leaf area of direct seeded rice at the different growth stages by 5-8%, 42-43%, 30-40%, 58-60% respectively. Varietal differences in plant height, tiller number and TDM were related to differences in growth rate and maturation period. Interaction

effects of variety x N rate were observed on grain yield and yield components. Higher N increased grain yield of IR 72, MR 142 and MR 84 by 49%, 43% and 26% respectively. Total N, P and K tissue content was increased by 35-68% with higher N application. At early stages of growth, varietal differences mainly involved P and K content but at heading included N, P and K content. There was however, no significant effect of P rate on all the parameters measured.

In the field trial, higher N rate significantly increased tiller number, TDM, tissue content of N, P and K at heading and final grain yield by 21%, 14%, 32%, 16-21%, 14% and 13%, respectively. Varietal differences were observed in tiller number and nutrient content at active tillering, TDM at active tillering and heading stages as well as percentage of filled grains. Interaction effect of variety x N rate was observed on panicle number only. However, there was no significant effect of P on all the parameters studied.

A higher rate of N (at least 120 kg ha^{-1}) is required for direct seeded rice. This is evident from the higher growth, yield and tissue content of N, P and K obtained at 120 and 160 kg ha^{-1} N from pot and field trials respectively as compared to 80 kg ha^{-1} N.

Abstrak tesis yang dikemukakan kepada
Senat Universiti Pertanian Malaysia bagi memenuhi keperluan
Ijazah Master Sains Pertanian.

KESAN PENGGUNAAN NITROGEN DAN FOSFORUS TERHADAP TUMBESARAN, HASIL DAN PENGAMBILAN ZAT MAKANAN PADI TABUR TERUS

OLEH

RAFEAH BTE ABDUL RAHMAN

Jun 1996

Pengerusi: Prof. Madya Dr. Surjit Singh

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Ujikaji dalam pasu dan di ladang menggunakan varaiti IR 72, MR 84 dan MR 142 telah dijalankan untuk menentukan kesan kadar N dan P terhadap tumbesaran, hasil, komponen hasil serta pengambilan zat makanan padi tabur terus. Ujikaji-ujikaji tersebut menggunakan rekabentuk Blok Rawak Lengkap dengan empat replikasi bagi ujikaji dalam pasu dan tiga replikasi bagi ujikaji di ladang.

Keputusan ujikaji dalam pasu menunjukkan kadar N yang lebih tinggi meningkatkan ketinggian pokok, bilangan anak, jumlah bahan kering (JBK) dan keluasan daun padi tabur terus di peringkat-peringkat pertumbuhan

sebanyak 5-8%, 42-43%, 30-40%, 58-60%. Perbezaan varaiti dari segi tinggi pokok, bilangan anak dan (JBK) berkait dengan perbezaan kadar pertumbuhan dan tempoh matang. Hasil dan komponen hasil dipengaruhi oleh interaksi varaiti x kadar N. Kadar N yang lebih tinggi meningkatkan hasil IR 72, MR 142 dan MR 84 sebanyak 49%, 43% dan 26%. Jumlah kandungan N, P dan K dalam tisu bertambah sebanyak 35-68% dengan kadar N yang lebih tinggi. Pada peringkat awal pertumbuhan, perbezaan varaiti hanya melibatkan kandungan P dan K tetapi pada peringkat pengeluaran tangkai termasuk kandungan N, P dan K. Bagaimanapun, kadar P tidak memberi kesan terhadap semua parameter yang diukur.

Di ladang, kadar N yang lebih tinggi meningkatkan bilangan anak, JBK, kandungan N, P dan K di peringkat pengeluaran tangkai serta hasil sebanyak 21%, 14%, 32%, 16-21%, 14% dan 13%. Perbezaan varaiti terdapat pada bilangan anak dan kandungan zat makan tisu di peringkat pengeluaran anak yang aktif, JBK di peringkat pengeluaran anak yang aktif dan pengeluaran tangkai dan juga peratusan biji bernas. Kesan interaksi varaiti x kadar N hanya terdapat pada bilangan tangkai sahaja. Bagaimanapun kadar P tidak memberi kesan yang bererti terhadap kesemua parameter yang dikaji.

Kadar N yang lebih tinggi (sekurang-kurangnya 120 kg ha^{-1}) adalah perlu untuk padi tabur terus. Ini dibuktikan oleh peningkatan tumbesaran, hasil dan kandungan N, P dan K dalam tisu pada kadar 120 dan 160 kg ha^{-1} N dalam kajian pasu dan di ladang berbanding dengan 80 kg ha^{-1} N.

CHAPTER I

INTRODUCTION

Direct seeding of rice has become a popular method of crop establishment in Malaysia as well as in many parts of Asia. Presently 40-60% of the total rice area in the country is direct seeded. It is extensively practised in the major granary areas of Muda and Seberang Perak and exclusively in Barat Laut Selangor. It is envisaged that eventually three-quarters of the total rice area in Malaysia will be direct seeded (MARDI, 1994).

However, direct seeding practice has often been associated with unstable and fluctuating yield in the major granary areas of Malaysia over the last decade (Supaad et al., 1991). Although direct seeding of rice helps to overcome labour shortage and reduces cost and time for crop establishment, it also has its defects. Yield of direct seeded rice is very much affected by the early establishment and produces unevenly-ripened and poorer quality grains than transplanted rice. Crop care is more difficult especially in terms of soil and fertility management due greater competition from weeds during establishment while water management needs to be more precise (MARDI, 1994).

Nevertheless, direct seeded rice has great potential especially if proper management and higher inputs are provided. Studies on successful farmers in the major granary areas revealed that high yields (more than 7 t ha^{-1}) were achieved with higher rates of fertilizer and improved management (Tay et al., 1990; MARDI 1994; Sariam and Zainal Abidin, 1995). Studies on direct seeded rice in Vietnam showed that high yields of up to 7.6 t ha^{-1} were possible with high fertilizer rates and lodging resistant varieties (Guong et al., 1995). Among temperate regions, rice yields in excess of 9 mt ha^{-1} from Australia and the United States through direct seeding are among the highest in the world (Hill et al., 1991; IRRI, 1993).

Direct seeded rice crop has a higher nutrient requirement as compared to a transplanted crop because of the higher plant density and greater production of biomass in the vegetative phase (Dingkuhn et al., 1990; 1991a and 1991b; Schnier et al., 1990a, 1990b). Thus, a direct seeded rice crop tend to develop nutrient deficiency at the reproductive stage of growth and senesce earlier. A different fertilizer management strategy as compared to transplanting, is therefore necessary to ensure adequate nutrient availability at the critical developmental stages for attaining high yield.

In Malaysia, the current fertilizer recommendation for rice is based on the methods appropriate for transplanting culture. Fertilizer for rice is subsidised by the government at a rate of 80:30:20 kg ha^{-1} N, P_2O_5 and K_2O

respectively regardless of method of crop establishment. A higher rate of 100:40:30 kg ha^{-1} is however, generally recommended for a direct seeded crop but studies have shown that there are differences in response due to fertilizer rates, timing, soil fertility, varieties and season (Xaviar, 1990; Xaviar et al., 1993; MARDI, 1994; Sariam, 1994; Sariam et al., 1995). However, most of the studies carried out locally were based on yield alone. Very little information is available on the nutrient uptake and performance of direct seeded crops, especially at the important growth stages and among different varieties. This information is necessary in order to obtain a better insight of the nutritional demand of the direct seeded crop so that adequate fertilizer is applied at the stages most critical for improved yield.

With this in view, this study was carried out with the following objectives:

i. to study the effect of varying N and P on crop growth, development and yield of different rice varieties.
ii. to study the effect of these treatments on nutrient uptake by the rice varieties at different growth stages, and
iii. to determine the amount of N and P fertilizer required for the varieties studied.

CHAPTER II

LITERATURE REVIEW

Direct Seeding of Rice

Direct seeding of rice by broadcasting has become a popular alternative to transplanting in irrigated rice culture of tropical Asia (De Datta, 1986). The widespread practice of direct seeding amongst rice farmers is attributed to the scarcity of farm labour and the cost effectiveness of this practice as compared to the transplanting (De Datta, 1986; Supaad et al., 1990; Guong et al., 1995).

In Malaysia, about 60 % of the rice granary areas practice direct seeding and this trend is expected to continue in future years to cover 75 % of the total cultivated area (Supaad et al., 1990; MARDI, 1994).

Direct seeding of rice was first attempted in Malaysia in Sekincan in 1973, which later spread to almost 100% of the irrigation block by the main season 1980/81 (Abdul Rahman, 1988). In Muda, initially only 1% of the area was direct seeded in 1980 but by the first season 1991, 99.6% of the area was under direct seeding (Ho et al., 1991; Mustafa et al., 1992). The extent of direct seeding in the other major granary areas in Malaysia is estimated to be more than 60% for S.Perai, 70% for Seberang Perak, 90% for Besut and 100% for Barat Laut Selangor (Supaad et al., 1990; MARDI, 1994).

However, direct seeding is not without its problems. Direct seeding rice cultivation was often associated with the declining and unstable rice production trend, especially in the off-seasons in Muda (Hiraoka et al., 1991). The reasons for the low yield of direct seeded rice were attributed to the unsystematic crop management practices such as poor seed establishment, poor weed control, inadequate inputs and the use of inappropriate varieties and not because of direct seeding per se (Supaad et al., 1990; Tay et al., 1990; Hiraoka et al., 1991). However, through experience and improved agronomic practices some top farmers in the major granary areas have attained yields ranging from 7.1 - 9.6 t/ha (Tay et al.,1990; Ho et al., 1991; Sariam and Zainal Abidin, 1995). In Muda, crop cutting tests carried out in main season of 1991 showed that overall, 71% of the farmers in that area achieved a yield of more than 5 t ha^{-1} and about 25% obtained yields of up to 7 t ha^{-1} (Mustafa et al., 1992). This proves that direct seeded rice has its prospects and it is believed that the major breakthrough in raising the potential yield of irrigated rice from the current 10-11 t ha^{-1} to 13-15 t ha^{-1} may come from direct seeded rice rather than transplanted rice (Tay et al., 1990; De Datta and Nantasomsaran, 1991).

Role of Nitrogen

Nitrogen is the most important nutrient for rice and is needed throughout the growth stages of the rice plant, from seedling up to maturity, for vegetative growth as well as for yield production. Nitrogen promotes formation of the different organs in the rice plant as well as other physiological processes. It is the major component for the development of tillers, leaves and grains and promotes protein and carbohydrate synthesis. At early growth stages N is needed for tiller formation and expansion of leaves which are important for photosynthesis (Murata, 1965). Nitrogen at later stages helps maintain green leaves and stimulates photosynthetic activity, improves uptake of nutrients and prevents decline of leaf area. Due to the enhancement of photosynthesis and mineral uptake, the number of ripened grains is increased (Wada, 1984).

Matsushima (1965) reported that N is also required at early growth for the production of panicle-bearing tillers, at reproductive and ripening stages for spikelet production and differentiation, and also for grain filling. Lack of N will reduce bearing tillers and cause spikelet degeneration and higher percentage of unfilled grains.

However, N is the most limiting nutrient element for rice production in the tropics and is universally deficient in tropical soils. New high yielding varieties bred for the tropics require high nitrogen inputs, before they can achieve their full yield potential (Stengel, 1979). As such, without fertilization, soils in the tropics are unable to maintain an adequate supply of N to match the removal and losses associated with high productivity (Singh, 1992). The increase in rice production in Indonesia as well as the reported 24% increase in rice production in Asia, from 1965 to 1980, were achieved mainly through an increase in the amount of fertlizer N applied to the rice soils (Sudjadi et al., 1987; IRRI, 1993).

Role of Phosphorus

Rice plant requires P for good growth and high grain yield (Kawaguchi and Kyuma, 1977). It is most important at early growth for cell formation (William and Joseph, 1970). Phosphorus promotes root development, tillering, early flowering, faster grain ripening and improves grain quality (Jones et al., 1982; Raju et al., 1992). Deficiency of P will result in narrow and shorter leaves, leaf chlorosis and earlier tissue death, longer crop maturation and higher percentage of unfilled grains (Jones et al., 1982). Application of P together with N and K, improves the nutrient uptake, but application of N alone even at high levels reduces nutrient uptake even though dry matter production is increased. This is due to the imbalance of the nutrients (Pande et al., 1993).

With varietal improvement and additional application of N, phoshporus will become a yield-limiting factor on many types of soil (Tanaka, 1975). Under double cropping and direct seeding culture, the rice crops remain longer in the rice fields and therefore removal of nutrient will be higher. With continuous direct seeding, the decrease in soil fertility is more serious and fertilizer application is thus critical. In Japan, P deficiency have been observed in direct seeded fields (De Datta, 1986).

Nitrogen Application

Nitrogen Response

High yielding rice varieties are very responsive to N application. Response to N varies with variety, soil fertility, season and cultural practices (Stengel, 1979; Mohd Aris et al., 1990; Xaviar, 1990; Dingkuhn et al., 1991a; Xaviar et al., 1993; Kropff et al., 1993; Sariam, 1994).

Indica varieties responds to high N by producing luxuriant vegetative growth whereas in *japonicas*, the absorbed N is used to increase grains (Matsuo, 1965). High biomass in high yielding *indica* varieties, especially at early growth stages, is a disadvantage as it is usually associated with a lower crop growth rate at later stages due to higher respiration (Akita, 1989). Yield is thus low because of unfavorable balance between photosynthesis and respiration. On the other hand, varieties with high growth rate at later stages generally produce high grain yield especially at high N.

The response to high fertilizer application is related to differences in physiological characters controlling ability for absorption and assimilation of N and other processes such as photosynthesis, translocation and storage of its products, growth of leaves and activity of roots (Matsuo, 1965). In some varieties, increase in N increases yield as a result of high number of panicles and spikelets per panicle. In others, increase in N led to yield decrease, due to lower percentage of filled grains and lower 1,000-grain weight. Application of N could also result in excessive vegetative growth leading to nutrient dilution and deficiency at later stages especially when not timely applied (Dingkuhn et al., 1992a).

In the tropics, response to N application is higher in the dry season than in the wet season because of high solar radiation at the reproductive and ripening stages of growth in the dry season (Tanaka et al., 1964; Xaviar, 1990; A'aini et al., 1991; Takanashi et al., 1993; Kropff et al., 1993; A'aini et al., 1994). The condition is more conducive for ripening and filling of the grains resulting in higher percentage of filled grains and higher 1000-grains weight.

On the other hand, in the wet season, temperatures are high during planting and high N results in vigorous growth but poor grain yield because solar radiation is lower than optimum during ripening (Tanaka and Vergara, 1967).

A greater response to N is also usually observed in less fertile soils than in more fertile soils (Xaviar, 1990; Takanashi, 1993; Sariam, 1994; Hung et al., 1995). The available soil-N is low in less fertile soils and therefore the rice crop have to depend more on fertilizer N to meet its requirement for growth and development. Higher organic matter content and greater mineralization in fertile soil results in greater availability of soil N causing a lower response to fertilizer N (Baker et al., 1994; Sariam et al., 1995).

There are differences in response to applied N between different crop establishment methods, with higher response to levels of N in direct- seeded than in transplanted rice crop (Muhammad, 1985; Mohd Aris and Yap, 1987; Mohd Aris et al., 1990; Schnier et al., 1990a; Xaviar et al., 1993; Sariam, 1994). In a multilocational fertilizer trial, higher yield in direct seeded rice resulted in a higher elevation of the response curve (Xaviar et al., 1993). Sariam (1994) reported that in direct seeded rice, positive response was observed at very high rates of fertilizer in a number of varieties tested. However, the reverse was observed by Takanashi (1993) where grain yield of direct seeded rice was lower than transplanted rice. The low response was due to higher N uptake during vegetative stage before panicle initiation, which led to luxuriant growth which did not benefit the crop at the later stages.

Rate of Nitrogen

Numerous studies on the differential rates of nitrogen have been carried out in rice, both transplanted or direct seeded. The rate of N required by rice differs with soil fertility, cultural practices, variety and season (Mohd Aris et al., 1990; Takanashi, 1993, A'aini et al., 1994, Hung et al., 1995).

Generally, a higher rate of fertilizer application is required when soil N and efficiency of fertilizer is low while in more fertile soils, higher yields were obtained at lower rates of N (Takanashi, 1993; Sariam, 1994; Sariam et al., 1995). Yield response to N fertilizer was significant up 240 kg ha^{-1} in Bertam where the soil was less fertile, whereas in more fertile soils as in Sekincan and Muda, higher yields were obtained at lower rate of N. In alluvial soil in China, highest yield was obtained from 174 kg N ha^{-1} while economic optimum rate of N was at 157.5 kg ha^{-1} (Wu et al., 1992).

Season also affects the response of rice to N application due to the differences in temperature and solar radiation between seasons. A'aini et al. (1994) reported significant interaction effects of season x N in transplanted rice, with generally higher response in off-season of Muda. In a direct seeded