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EVALUATION OF NITROGEN AND POTASSIUM UPTAKE AND EFFICIENCY OF TWO RICE VARIETIES ON BEKENU SERIES

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BY

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To My Beloved Family
Dad, Mohd Yusob Darus, Mom, Mariam Langkat
and to all my sisters; Yusmizawati, Mariani, Zarina, Nurawatif, Nurmuthmainnah
Thank you for your love, morally supported, constantly counseled and persistently helped me throughout this research…

ABSTRACT

A pot study was carried with the following objectives: (i) To investigate N and K uptake of MR 220 and ARC 2 rice varieties on Bekenu series (Tipik Tualemkuts), and (ii) To investigate N and K use efficiency (MR 220 and ARC 2) of soil applied urea and KCl on Bekenu series. Treatments evaluated were: (i) MR 220 and ARC 2 under fertilized condition (T1), and (ii) MR 220 and ARC 2 under unfertilized condition (T0). The experiment was conducted in a glasshouse at Universiti Putra Malaysia Bintulu Campus, Sarawak, Malaysia. Altogether 24 pots were used having a completely randomized design (CRD) with 6 replications (for each treatment and each variety). Nitrogen and K were applied in the forms of urea (46 % N) and muriate of potash (60 % K_2O) for the two varieties. For T1 of MR 22O, N, K, and P were applied at the rates of 4.0 g N, 1.10 g K_2O and 2.13 g P_2O_5 per pot respectively in split. In the case of T1 of ARC 2, N, K, and P rates were 1.30 g N, 0.8 g K_2O, and 1.70 g P_2O_5 per pot respectively in split. At 65 days (ARC 2) and 70 days (MR 220) after planting, plants were sampled and partitioned into roots and stem, and their dry weight, N, and K concentrations determined using standard procedures. Soil sampling was done before and after fertilization. Soil total N was determined using the Kjeldahl method while exchangeable K, Ca, Mg, and Na were extracted using the double acid method and their concentrations determined using atomic absorption spectrophotometry. Dry ashing method was used for the determination of K, Ca, Mg and Na concentrations in plant tissues while the Kjeldahl method was used to determine total N in plant tissues. The concentrations multiplied by the oven dried weight of roots and stem represented N, K, Ca, Mg and Na uptake in these plant parts. The N and K use efficiency was then calculated using the subtraction

method. With the exception of Ca, urea and KCl application significantly increased soil N, K, Mg, and Na concentrations. Application of K fertilizer significantly increased soil exchangeable K under MR 220 and ARC 2 cultivation. But this accumulation did not reflect in significant plant growth (height and number of panicles), dry matter production, K uptake and K use efficiency. Urea application significantly increased N concentration in both roots and stem of MR 220 but the significant effect of N reflected in stem only. Urea application however, did not affect N accumulation, plant height, number of panicles, and dry matter production. Nitrogen use efficiency was also low. As the results showed inefficient nutrient use, series of trials on Bekenu series on the interaction between inorganic and organic fertilizers (e.g. compost) should be carried out as this is likely to improve the inherent low exchange properties of this soil that partly contributes to poor fertility properties.

ABSTRAK

Satu kajian di dalam pasu telah dijalankan dengan objektif seperti berikut: (i) untuk mengkaji pengambilan N dan K oleh varieti MR 220 dan ARC 2 pada tanah siri Bekenu (Tipik Tualemkuts) dan (ii) mengkaji kecekapan penggunaan N dan K pada tanah siri Bekenu setelah baja urea dan KCl diaplikasikan pada MR 220 dan ARC 2. Penilaian rawatan adalah: (i) MR 220 dan ARC 2 dengan pembajaan (T1), dan (ii) MR 220 dan ARC 2 tanpa pembajaan (T0). Eksperimen di jalankan di dalam rumah kaca dengan menggunakan 24 buah pasu di Universiti Putra Malaysia Kampus Bintulu, Sarawak, Malaysia secara CRD dengan 6 replikasi (untuk setiap rawatan dan varieti). Nitrogen dan K diaplikasikan dalam bentuk urea (46 % N) dan "muriate of potash" (60 % K_2O) pada kedua-dua varieti. Untuk T1 pada MR 220, kadar pembajaan N, K dan P untuk setiap pasu masing-masing adalah sebanyak 4.0 g N, 1.10 g K_2O dan 2.13 g P_2O_5 dengan pembajaan secara pembahagian. Untuk T1 ARC 2 pula, kadar pembajaan N, K dan P bagi setiap pasu masing-masing.adalah sebanyak 1.30 g N, 0.8 g K_2O dan 1.70 g P_2O_5 dengan pembajaan secara pembahagian. Pada hari ke 65 (ARC 2) dan hari ke 70 (MR 220) selepas penanaman, pensampelan pokok padi dilakukan dengan membahagikannya kepada akar dan batang, dan berat kering, kepekatan N, dan K pokok padi ditentukan mengikut prosedur yang biasa. Pensampelan tanah dilakukan sebelum dan selepas pembajaan. Jumlah N tanah ditentukan menggunakan kaedah Kjeldahl manakala pertukaran K, Ca, Mg, dan Na diekstrak menggunakan kaedah "double acid" dan kepekatan ditentukan menggunakan AAS. Kaedah "dry ashing" digunakan untuk menentukan kepekatan K, Ca, Mg, dan Na di dalam tisu tanaman sementara kaedah Kjeldahl digunakan untuk menentukan jumlah N. Kepekatan yang diperolehi di darab dengan berat kering oven akar dan batang memberikan jumlah pengambilan N dan K oleh

bahagian tumbuhan tersebut. Kecekapan penggunaan N dan K dikira menggunakan kaedah penolakan. Dengan pengecualian Ca, aplikasi urea dan KCl (MOP) yang memberikan peningkatan signifikan pada kepekatan N, K, Mg, dan Na dalam tanah. Aplikasi pembajaan K telah meningkatkan pertukaran K secara signifikan pada pokok padi MR 220 dan ARC 2. Tetapi pengumpulan ini tidak memberikan kesan secara signifikan pada pertumbuhan pokok (ketinggian dan jumlah bilangan panikel), penghasilan berat kering, pengambilan K dan kecekapan penggunaan K. Aplikasi urea memberikan peningkatan secara signifikan terhadap kepekatan N pada kedua-dua bahagian akar dan batang MR 220 tetapi kesan signifikan hanya berlaku pada bahagian batang sahaja. Walau bagaimanapun, aplikasi urea tidak memberikan kesan terhadap pengumpulan N, ketinggian pokok, jumlah bilangan panikel, dan penghasilan berat kering. Kecekapan penggunaan Nitrogen juga adalah rendah. Dengan keputusan penggunaan nutrient yang kurang efisien yang telah ditunjukkan, lebih banyak siri percubaan pada tanah siri Bekenu terhadap interaksi diantara pembajaan organik dan bukan organik seperti kompos haruslah dilaksanakan kerana ianya dapat memperbaiki ciri-ciri pertukaran tanah yang rendah secara semulajadi yang merupakan faktor penyebab kepada ciri-ciri ketidaksuburan tanah.

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APPROVAL SHEET

I certify that this research project report entitled "Evaluation of Nitrogen and Potassium Uptake and Efficiency of Two Rice Varieties on Bekenu series" has been examined and approved as a partial fulfillment of the requirement for the degree of Bachelor of Bioindustry Science in the Faculty of Agriculture and Food Sciences, University Putra Malaysia Bintulu Campus.

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N	Nitrogen
P	Phosphorus
K	Potassium
Ca	Calcium
Mg	Magnesium
Na	Sodium
S	Sulfur
C	Carbon
H	Hydrogen
O	Oxygen
Mn	Manganese
Cu	Copper
Zn	Zinc
B	Boron
Cl	Chlorine
CEC	Cation Exchange Capacity
AAS	Atomic Absorption Spectrophotometry
SAS	Statistical Analysis System
T1	Fertilized Treatment
T0	Unfertilized Treatment
DAP	Days After Planting
DAS	Days After Seeding
DW	Dry Weight
MOP	Muriate of Potash
CIRP	Christmas Island Rock Phosphate
KCl	Potassium Chloride
≤	Less than or equal to

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) is an important food crop in Malaysia and forms the staple diet of the Malaysians. Rice is grown for its grain yield. The observed yield capacity of rice varieties and their adaptability are inter-related. A variety that gives a high yield at a location is obviously adapted to the location and the responsiveness to fertilizers. Nitrogen, P, and K are the three essential elements for a high stable yield with modern rice varieties. Past studies have shown that N has been most contributively enhancing yield by a magnitude of 0.8-1.5 t/ha (Aralundoo *et al.,* 1987). Phosphorus applied as soluble phosphate at the rate of 40 kg P_2O_5/ha increased yield by about 0.3-0.8 t/ha, particularly in the riverine alluvial soils (Aralundoo and Mohammad, 1987).

Fertilizer recommendations for the major rice areas of the country have been made from time to time. The fertilizer recommendations have taken into considerations a wide range of important factors namely the type of rice varieties grown, long term soil effects, seasonal effects, specific environmental constraints in the area and the margin economic return to the farmers. Nitrogen is the most important yield increasing fertilizer but to maintain yields at high level, the N must be balanced with P and K as yield stabilizing fertilizers (Von Uexkull, 1976). The organic matter in the paddy soil itself is a major source of N for the rice crop. The soil contains about 1,000 to 6,000 kg N/ha mostly in organic forms (Yoshida, 1976).

The rice plants usually accumulate very little N during grain fill. Most of the N in the grain comes from N remobilized and translocated from the rice stems and leaves. Consequently, the uptake of fertilizer N early in the season affects the uptake of the native soil N later in the season, the size of dry matter production of the rice plant, the harvest index or sink-source relationships of the rice plant and thus ultimately the rice grain yield (Guindo *et al.,* 1994a,b).

Fertilizer use efficiency is output of any crop per unit of the nutrient applied under a specified set of soil and climatic conditions. For optimum growth and yield, rice requires that N be in adequate supply in the soil for uptake at the beginning of the raid growth (tillering) period. The numbers of panicle per unit area is determined by either stand density or tiller development during vegetative growth and is the first yield component determined (Stansel, 1975).

The requirement of rice crop for K is much greater than for either N or P. Over 80 % of the absorbed K by the plant is found in straw. Need for K is most likely to occur on sandy soils. Land submergence reduces ferric and manganese leading to increase in their concentration in soil solution and these ions exchange with K on the exchangeable complex and release it in soil solution. Hence, the availability of native K increases in rice soils on flooding. Potassium deficiency is often associated with Fe toxicity, which is common on acid and acid sulphate soils. Its deficiency also occurs on poorly drained soils. Generally, response of rice to added K is not marked as for N and P. Most soils in Asia do not need K as much as N or P and only small and available increases in yield is obtained with added K fertilizer. Rice soils in high rainfall area that are deficient in K may respond to addition of K fertilizers.

Bekenu series is a member of the Bekenu family which is fine loamy, siliceous, isohypherthermic, red yellow to yellow Tipik Tualemkuts (Paramanathan, 2000). It has been characterized by their deep, well drained profiles with brownish yellow to yellow subsoil color. This series has low fertility status but with good fertilization and conservation practices wide range of crops including rice could be grown on these series. If rice yields in this environment can be stabilized and improved, resources could be reallocated and possibly invested in more remunerative activities. Moreover, income from rice farming, although small, does constitute an important share of total income, especially for poor farmers, and any improvement of productivity will directly benefit these household.

MR 220 is high yielding, capable of producing yields around 10 tonnes per hectare if grown under appropriate environments and precise management practices. It requires slightly high fertilizer inputs than usual in order to produce high yields. This variety is also very suitable for the direct seeding culture (Alias *et al.,* 2005). Saratani ARC 2 is a short term rice variety suitable for double cropping in Sarawak. The plant is of medium height with stem (culms) measuring about 105-110 cm. The stems are strong and do not lodge easily. This variety is suitable for transplanting and direct seeding (DOA, 2005). Taking into consideration the aforementioned attributes of rice MR 220 and ARC 2 and the effect of soil type, there is little information on nutrient uptake and yield of these varieties on acid soils of Sarawak such as Bekenu series not to mention estimation of the varieties' N and K use efficiencies. Thus, the objectives of this study were:

1. To investigate N and K uptake of MR 220 and ARC 2 varieties on Bekenu series.

2. To investigate N and K use efficiency of soil applied N and K fertilizers on Bekenu series.

CHAPTER 2

LITERATURE REVIEW

2.1 Fertilizers

Paddy, like every other plant, requires a number of different plant foods in sufficient amounts and in the correct proportions to give the maximum yield. Some of these foods are required in large amounts of major elements such as N, P, K, Ca, Mg, S, C, H and O. Other nutrients that are only needed in small amounts that are called trace elements include Fe, Mn, Cu, Zn, B, and Cl. Most of these nutrients are obtained from the soil, water or the air but sometimes they are not sufficiently available for plant growth and development as a result, the need for application of balanced fertilizers.

2.1.1 Nitrogen

Fertilizer, especially N, application only at the time of puddling and or plowing had been a common technique until the 1960's in Japan. This cultivation technique resulted in severe lodging due to straw elongation, reduced grain-filling, and low economic yield. However, the use of split application of fertilizer, at the time of plowing and or puddling, at about 1 week after transplanting, at the late maximum tillering stage, and at the grain-filling stage has largely improved the growth pattern of the rice plant, and increased yield of the tall cultivars prior to release of the semi-dwarf cultivars. In studies on the split application of fertilizer, Matsushima and Manaka (1960), and Matsushima (1976) found that fertilizer application at the panicle-base initiation stage about 30 days before heading increased length of leaf blades present during the grain-filling period, and of the flag, penultimate, and one or two lower leaves and their corresponding internodes, and increased the number of spikelets per panicle.

The magnitude of fertilizer losses determines the N utilization efficiency. Excessive N loss is not only undesirable economically; it is also detrimental to the environment. Gaseous loss of N through the denitrification and ammonia volatilization involved complex biochemical processes, thus it is affected by many factors. Some of the important factors affecting ammonia volatilization are soil pH, urease activity, soil, CEC, organic matter content, and wind velocity (Bouwmeester and Vlex, 1981; Katyal and Gadalla 1990), while the denitrification loss is affected by soil redox potential, microbial activities, organic carbon and soil pH (Reddy and Patrick 1986).

2.1.2 Potassium

Potassium was not considered as important particularly in the marine soils in the west coast of Peninsular Malaysia. Potash application was thought to be necessary only in sandy soils low in clay content, peaty soils and in strong lateritic soils. Kanapathy (1972) reported that application of K tends to depress the grain yield of rice. Von Uexkull (1970) attributed poor K response to wrong timing of application, resulting in a disturbed N/K within the rice plant. Maintenance of specific N/K balance is imperative for crops such as rice which absorbs N in the ammonium form than in upland crops which absorbs N in the nitrate form.

Potash applied as a basal dressing may suppress N uptake and adversely affect tillering of rice plant. Field trials conducted on a wide range of soil conditions in Kemubu from 1973-1978, clearly indicated that K did not increase grain yields even when the other major nutrients were high (Embi and Shuhaimen, 1980). Analysis of K content in the straw and grain samples did not exhibit any deficiency trend even in the control plots. It appears that sufficient K is available in the soil and irrigation water to meet the requirement of the present 3.5-4 t/ha yield potential. Kanapathy (1968) concluded that the presence of 1.5 ppm of K in irrigation water is sufficient for padi yield of 3-4 t/ha.

2.2 Factors Affecting N and K Uptake

The process of nutrient uptake at different stages of growth is the function of climate, soil properties, amount of fertilizers applied, the variety of the rice plant and the method of cultivation.

2.2.1 Climate

Rainfed lowland rice (*Oryza sativa* L.) is grown in bunded fields by some of the poorest subsistence farmers in the world. Crop performance is variable, due to different seasonal conditions and spatial heterogeneity over soil types and topographic positions. Consequently, agro hydrology may vary from field to field (Wade *et al.,* 1999a). Drought stress is commonly considered the most severe limitation to productivity, but ponding or even complete submergence may occur during the cropping season. Drought is complex in rainfed lowland, as it may occur early in the growing season or from flowering to grain filling, and may follow a period in which soils were flooded and anaerobic (Wade, 1999b).

Studies by Samy *et al.* (1971) and Nozaki *et al.* (1977) had shown that climatic factors that cause soil drying prior to the dry season crop have a pronounced effect in improving soil fertility and crop yield. It is evident that drying of paddy soil before submergence improves the growth of rice plant in comparison to fields that are not dried (Mitsui, 1960). This is due to the accumulation of inorganic nitrogen in the soil by microbial mineralization of soil organic nitrogen.

Only a relatively small part of a soil capacity to adsorb cations is normally occupied by K. Most of it is taken up by H, Ca, Mg and Na. In humid regions the Na values are usually so low as not to merit consideration, but in arid regions Na values may be relatively very high. In humid regions the tendency is for H to occupy more and more of the cation-exchange complex at the expense of the exchangeable Ca, Mg and K that were used by crops or lost in the drainage waters. The remedy lies in applying alkaline form of Ca, normally ground limestone, the Ca replacing the H in the exchange complex. Some of this Ca, and the Mg usually associated with it in limestone, can then be replaced by K through the use of a fertilizer that is high in this element.

2.2.2 Soil Properties

The yield of a rice crop is a function of soil on which it is grown, apart from its genetic potential, climate and management. Consequently, when a particular crop variety which has an ideal plant type to utilize solar energy, and the supply of fertilizers are abundant, the factors which control crop growth will be the properties of the soil.

Variation in soil chemical, physical and biological properties has two important consequences on plant nutrition. Firstly, there is the quantitative relationship between nutrient supply (amount and rate) and uptake by the plant related to nutrient concentration in the soil solution. Secondly, the interaction, of nutrients in the uptake phase imposed by the contrasting ratios of nutrients. Both these factors have strong influences on the production potential of rice varieties having widely different ecological requirements.

The fertility of the rice soil in Peninsular Malaysia depends largely on the nature of the parent materials and drainage class of the respective soils (Suhaimi *et al.*, 1986). These are the factors of soil environments that contribute to the distinct variation in rice yield between and within rice growing areas. Considering soil chemical properties alone, Ismail *et al.* (1990) concluded that 9 and 6 varieties at zero and standard (90:30:20) NPK fertilizer rates, respectively could explain the rice yield variation in granary area in Peninsular Malaysia. The soil chemical properties considered accounted for about 73 and 58 % of the rice yield variation at zero and standard fertilizer rate. The common soil properties that significantly affect rice yield under both fertilizer rates were N, CEC, exchangeable Ca, total P and base saturation (including K).

Rice grows on a variety of soils ranging from well drained to poorly drain on waterlogged soils. Land on which rice is grown may be differentiated into three classes: the Pluvial, Phreatic, and Fluxial and classes depending on topography and water supply (Moorman and Van Breeman, 1978). Ng (1967) has reported that most of the paddy soils are heavy textured and the clay mineralogy, cation exchange capacity (CEC) and organic matter content provide the most useful basis for differentiating paddy soils.

Low soil fertility is also complex, because a large number of nutrients may be in limited supply, or toxic conditions may be present where soils are acid or saline (Wade *et al.,* 1998; Fukai *et al.,* 1999). The fluctuation in soil conditions from anaerobic to aerobic also has enormous consequences for nutrient availability (Burford *et al.,* 1989). Thus, yields in rainfed lowland average only 2.3 t/ha over the 38.7 m/ha grown (IRRI, 1993). Nutrient status of soils in rainfed lowland is often poor and response to applied nutrients is often modest (Lathovilayvong *et al.,* 1997; Mazid *et al.,* 1998). The magnitude of response may not be closely related to soil test values for critical elements (Angus *et al.,* 1990). Thus, little fertilizer is applied in these systems (Khunthasuvon *et al.,* 1998; Linquist *et al.,* 1998). Nutrient responses may be variable, especially on soils of high sand content (Lathovilayvong *et al.,* 1997), or under the influence of insufficient or excess water.

In flood, N and K fertilizers may be washed away. In drought, N and K fertilizer may be unavailable in dry surface soil. Or the farmers may simply decide not to apply fertilizer if they perceive there to be little chance of the dressing being effective. Farmers adjust their fertilizer dressings based on their expectation of whether the season will be favourable (Wade *et al.,* 1998). Usually, this is determined by whether ponded water is present. The time of disappearance of ponded water relative to time of flowering has been related to yield reduction in late season drought (Jearakongman *et al.,* 1995), even when the soil remained moist. This response was attributed to a drop in soil pH when free water disappeared, leading to a decline in availability of nutrients, especially of P and Fe (Khunthasuvon *et al.,* 1998; Fukai *et al.,* 1999).

2.2.3 Amount of Fertilizer

Vo Tong Xuan (1974) pointed out that many farmers growing irrigated rice used fertilizer, but used wrong methods of application and were not able to calculate the correct amount of fertilizer required. In most cases they did not incorporate a basal application and applied either too much or too little. Application of N fertilizer to lowland rice has consistently increased crop yield. Urea is dominant N source in lowland rice. In addition to denitrification and leaching losses encountered by other N fertilizer, urea is also subjected to ammonia volatilization loss (De Datta *et al.*, 1991). Thus due to high N loss it is not uncommon to find that the N utilization efficiency of rice applied with urea to be less than 50 % (Vlek and Byrness 1986; Khanif, 1988).

Potassium balances in rainfed rice are particularly precarious because rainfed rice does not receive K in irrigation waters, which is an important part of the K balance in irrigated rice (Greenland, 1997). Also, resource-poor rainfed lowland farmers generally either remove all the straw from their fields for fuel and animal fodder or they burn it (Von Uexkuell and Beaton, 1992). They do not have access to the necessary machinery for incorporating residues in the soil. In light-textured soils, additional K may be lost through leaching. In proportion as more and more K is added to the soil in the form of such fertilizer salts as potassium chloride, sulphate or nitrate, K fixation may occur. This results from its penetration into the interior of the lattice structure of the clay particles, notably those of the montmorillonitic types. Release from such a location as readily affected as it would be if the element was adsorbed on the surfaces of these particles. But the availability of this K to plants is increased as the supplies in the readily exchangeable state are reduced through the growing of crops that are harvested and removed from the field.

2.2.4 Variety of Rice

Although there are many rice varieties in the world, no one variety can be found everywhere. The most suitable variety in one place is selected on the basis of its ability to give a high and constant yield under the circumstances of the climate and the soil condition of that district. Studies have shown that rice cultivar performance differs among the environments of the region, with the variance due to cultivar by environment interaction being 3-5 times greater than that due to cultivar alone (Cooper and Somrith, 1997). Many irrigated experiments have demonstrated differences among rice cultivars in response to fertilizer application, particularly N, under irrigated conditions (De Datta *et al.,* 1968). The largest yield response to applied N occurs in semidwarf cultivars as they do not lodge readily. Traditional, subsistence farmers of the rainfed lowlands, however, favour taller cultivars because of their tolerance to flooding and their competitiveness against weeds.

With increased cost of fertilizer and reduced profit associated with rice cropping in recent times, development of cultivars that are adapted to low soil fertility is desired. Ideal cultivars would be those that perform well under low soil fertility but also respond well to applied fertilizer (Ladha *et al.,* 1998). Modern cultivars with high harvest index are often more efficient in nutrient use and higher yield per unit of nutrient uptake (Vose, 1990). Hence, they may perform better than traditional cultivars in all environments including low input conditions.

MR 220 variety is a sister line to variety MR 219. It was developed from a cross between the two potential lines, MR 151 and MR 137. This variety is high yielding, capable of producing yields around 10 tonnes per hectare if grown under conducive environments and precise management practices. It requires slightly high fertilizer inputs than usual in order to produce high yields. This variety is also very suitable for the direct seeding culture. The plant type is similar to MR 219 which is erect and slightly tall. The flag leaves are also erect with green to dark green colour. MR 220 is classified as a short maturation variety. The grains belong to long grade rice with good eating quality. The variety is also resistant to most major pests and diseases of rice (Alias *et al.,* 2005).

Saratani ARC 2 is a short term rice variety suitable for double cropping in Sarawak. This variety is the outcome of extensive selection and evaluation of material originally introduced from Thailand. The plant is of medium height with stem (culms) measuring about 105-110 cm. The stems are strong and do not lodge easily. This variety is suitable for transplanting and direct seeding.
Saratani grows well in both irrigated and rainfed areas. During the main season, this variety can be harvested 118 days from the date of sowing, while during the off season 116 days. Compare to other varieties in Sarawak, Saratani matures

about 3-4 weeks earlier than MR 30, 4-6 weeks earlier than traditional varieties such as Biris, Rotan and Bario. In addition, Saratani is also a good yielder capable of producing 4.5-6.0 t/ha compared to 3.0-4.9 t/ha for MR 30 and 2.8-3.5 t/ha for traditional varieties in an area that is good in water and crop management. Saratani is highly resistant to blast (DOA, 2005).

2.2.5 Method of Cultivation

There are many practices in rice culture such as the direct-seeding and transplanting system. Direct seeded flooded rice is gradually replacing transplanted rice in Peninsular Malaysia. Current estimate indicates that extent of direct seeding area in Muda, Seberang Perai, Seberang Perak, Barat Laut Selangor and Besut is in the order of 70 >60 >70 >50 and 90 % respectively (Supaad *et al.,* 1990). Farmers use the current high-yielding varieties which were bred for the transplanted culture.

To achieve maximum yield, direct seeded crop requires greater N and probably K input than the transplanted crop due to its higher planting density. This difference is associated with over production of vegetative materials such as leaves and tillers in direct seeded crop during the period of linear growth, resulting in the dilution of resorted N and subsequently, foliar N deficiency. As a result, direct seeded crop tends to have lower growth rates during the ripening phase, have earlier senescence and lower harvest index (HI) than transplanted rice (Dingkuhn *et al.,* 1991).

2.3 Bekenu Series

The main limiting factor for the use of Bekenu series is because of the low fertility status and the terrain on which these soils occur. In the past in Sarawak, soils of the Bekenu series were mapped as Red-Yellow Podzolic soils which can either have a cambic, Kandic or orgillic horizon with hues of 10 YR or 2.5 Y with any CEC clay value. They are redefined here as soils having only an argillic horizon with red-yellow to yellow colour class and a CEC clay of less than 24 cmol (+) kg^{-1} clay in all sub horizons between 25 to 100 cm depth.

Little is known about the range in characteristic of the Bekenu series. They generally occur on rolling, hilly to steep terrain. On the steeper terrain the profiles become moderately deep and are no longer the Bekenu series. Textures in this soil are uniformly fine sandy clay loam and colours are brownish yellow, yellow to olive yellow. Only the deep soils are retained as belonging to the Bekenu series in this redefinition. CEC clay values are higher than 16 but less than 24 cmol (+) kg^{-1} clay (Paramanathan, 2000).

2.4 Fertilizer Management

2.4.1 Time of Fertilizer Application

Proper application timing is equal in effective N and K fertilizers management in rice to choose the proper N and K fertilizer sources and rates. Proper application timing, however, is more controversial due to misunderstanding concerning the N uptake characteristic of the rice plant, the shift over the last two decades from tall, leafy, lodging-susceptible cultivars to higher-yielding lodge-resistant semi dwarf and short stature rice cultivars, the influence of soil characteristics on N fertilizer availability and loss and water management.

MR 220 variety gives good responses to fertilizer especially N fertilizers. Thus, the N fertilizer should be applied at 4 stages; at 3 leaves stage, vegetative stage, panicle initiation stages and maturing stage. Subsidized fertilizer that was applied (260 kg of mixed fertilizer and 100 kg urea per hectare) was not enough to get higher yield and need to add with basal dressing (12:12:17+TE or 13:13:21+TE) with the rate 500 and 700 kg/ha (Alias *et al.,* 2005).

First fertilizers application was done at 15 days after direct seeding at a rate of 140 kg/ha to enhance roots and early growth of the plants. Second application was done at 30-35 days after direct seeding at 100 kg/ha mix fertilizer (5 bags/ha) and 100 kg/ha urea (5 bags/ha). Sixty percent of the basal dressing was applied at 50-55 days after planting where a balance of 40 % was applied at 70-75 days after planting. The third application is done at 50-55 days after direct seeding in order to maintain the growth of the plant while the fourth application on 70-75 days after direct seeding are very important in order to increase the weight of the grains (Alias *et al.,* 2005).

2.4.2 Form of Fertilizer

Water management, soil pH, and N source play a large role in efficient N fertilizer uptake by rice and thus on the N rate needed. More N fertilizer will be needed if there is an inability of flood the field in a timely manner following N fertilizer application. This is true if urea is applied to soil with a pH >7, due to increased probability of NH_3 volatilization losses.

Exchangeable (labile) and solution K concentration were reported to be highest in the top 5 cm of a flooded De Witt silt loam and decreases with depth (Teo *et al.,* 1994). The highest concentrations of available K near the soil surface are readily accessible to rice since the fibrous root system of flooded rice has a large surface are for nutrient uptake and at least 90 % of the total rice root length is in the top 20 cm of the soil during the growing season (Teo *et al.,* 1995c). Teo *et al.* (1995a) established that diffusion is the dominant factor controlling K availability to rice grown on flooded soils.

Some precautions with respect to timing and placement may be necessary with urea (Ignatieff, 1955). Urea contains N in the water-soluble amide form. Since this form cannot be fixed by soil colloids, some loss may occur through leaching if urea is applied as a basal treatment. This is particularly true if flooded water is added immediately after fertilizer treatment. A delay of 2 or 3 days in water application will permit its change to ammonium carbonate. This form is immediately adsorbed by the clay and organic particles of the soil. However, studies in Japan negate this concept with respect to urea. They report best results when the material was placed deep and irrigated immediately. Results are essentially the same as with ammonium sulphate. Rice-research workers in the United States have not reported serious losses of urea by leaching (Reynolds, 1954).

2.5 Summary

There are many factors that affect the N and P uptake by the plants where these entire factors should be consider in order to avoid the excessive use of fertilizer and also reducing the cost of the fertilizer among farmers. The flooded environment in which rice is grown, gives an impact on N and K uptake efficiency that rice can be the most efficient or inefficient of the agronomics crops depending on how these fertilizers that are applied and managed. Some precautions may be necessary with respect to proper timing, correct amount of application and placement of the fertilizer to maintain the availability and losses of the fertilizer. With increased cost of fertilizer and reduced profit associated with rice cropping in recent times, the ideal cultivars that would perform well under low soil fertility but respond well to applied fertilizer is desired.

The planting method and types of the soil also have strong influence on the amount of fertilizer N and soil N uptake by plants. The direct-seeded plant removes more fertilizer N than transplanted plants either at maximum tillering or at maturity. However, the proportion of N derived from fertilizer and soil N of both planting methods are similar.

Besides that, the physical, chemical and biological properties of the soil also affect nutrient uptake of the plants. Low soil fertility because a large number of nutrients may be in limited supply or toxic conditions may be present where soils are acid or saline. The fluctuation in soil conditions from anaerobic to aerobic also has enormous consequences for nutrient availability. Eventhough the Bekenu series has low fertility status, low water holding capacity, and high erodibility, but with much fertilization and good maintenance, they could be used for rice production.

The fertilizer uptake and the efficiency of the rice plants to ensure good growth and high yield depend on the types of the soil, climate, types of fertilizer, varieties of the rice and method cultivation. Each of their characteristic shows a different behaviour with the different situation and condition. Thus, the N and K uptake of MR 220 and ARC 2 on Bekenu series will show a significant response with the presence of the fertilizer.

CHAPTER 3

MATERIALS AND METHODS

3.1 Experimental Site and Methods of Planting

The experiment was a pot study and conducted in a glasshouse at the Universiti Putra Malaysia Bintulu Campus, Sarawak. The type of soil used in this study was Bekenu series. The test crops in this study were MR 220 and ARC 2 varieties. Based on the soil`s bulk density, plastic pots measuring 36 cm (height) x 30 cm (diameter) were filled with soil samples until the bulk of these soil was attained. The soils in the plastic pots were flooded to 5 cm water above the surface and were monitored from time to time. The rice seedlings were seeded at a rate equivalent to 140 kg/ha for MR 220 variety and 25 kg/ha for ARC 2.

It should be noted that for a good establishment, seeds of MR 220 and ARC 2 were soaked for 36 hours in water and left in moist condition with shading for 24 hours on wet tissue. The depth of the planting holes ranged from 2-4 cm where the sowing was done by hand and regulated by the number of seeds per throw. Seeds were sown directly in each planting hole. The planting holes were partially covered by loose materials from the surface to allow quick emergence of the seeds. There were 12 seeds per pot for ARC 2 and 35 seeds per pot for MR 220. Before the experiment was started, the soil was analyzed for bulk density, pH, total N, exchangeable K, Mg, Ca, organic matter, and Cation Exchange Capacity (CEC).

3.2 Soil Analysis before Planting

3.2.1 Soil Bulk Density

Soil bulk density is referred to as the mass (weight) of soil per unit volume of undisturbed soil or bulk soil volume whereas soil particle is defined as the mass (weight) of a unit volume of only particles (no air and water). In this study, the coring method was used to obtain the bulk density of the soil (Tan, 1996).

3.2.2 pH of Soil

Soil pH indicates the degree of acidity or alkalinity of soils. There are various ways to determine soil pH but in this research only the most commonly used procedure which is the potentiometric method was used. To determine the pH in water and pH in 1 N KCl, pH meter and pH buffer solutions were used. Ten gram of the soil samples was used in determining pH in water and pH in KCl where the reading of the soil pH in KCl was taken after 15 minutes while the soil pH in the water was taken after it was left overnight. A ratio of 1:2 (soil to water/KCl) was used.

3.2.3 Determination of Total N in Soil and Plant

Total N was determined using micro-Kjeldahl method (Bremner, 1965). Half a g (0.5 g) of soil, paddy stems and roots were weighed into 50 mL Kjeldahl digestion tubes and treated with 5 mL concentrated sulphuric acid and one tablet of Kjeldahl catalyst (mixture of high selenium and sodium sulphate anhydrous) added to each sample. The samples were shaken and allowed to equilibrate for 30 minutes after which they were digested on digestion block in a fume chamber. The samples were initially heated at 180 ^{o}C for 1 hour and then to 320 ^{o}C for 4-5 hours until samples became colourless, and they were then allowed to cool down. Afterwards, the samples were transferred into 50 mL volumetric flasks, diluted to the volume using distilled water, and then filtered through Whatman filter paper number 2. Ten mL of the filtrates were distilled with 10 mL of 30 % NaOH and the ammonium collected into 50 mL Erlenmeyer flask containing 10 mL of 2 % boric acid-indicator mixture (bromocresol green-methyl red). Total N was determined by titrating the distillates with 0.01 M HCl.

Percentage of N in soil or plant was calculated as:

$$\% N = [(V-B) \times M \times R \times 14.01/ Wt \times 1000] \times 100$$

Where:

V = Volume of 0.01 M HCl or H_2SO_4 titrated for the sample (mL)

B = Digested blank titration volume (mL)

M = Molarity of HCl or H_2SO_4 solution

14.01 = Atomic weight of N

R = Ratio between total volume of the digest and the digest volume used for distillation

Wt = Weight of air-dry soil or plant sample (g)

3.2.4 Determination of K, Ca, Mg, and Na in Bekenu Series

In this research, the double acid method (Tan, 1996) was used to extract the exchangeable K, Ca, Mg, and Na in soil. Forty mL of 0.05 M HCl: 0.025 M H_2SO_4 and another 40 mL of distilled water were added to 10 g of soil samples in plastic vials. The plastic vials were then shaken for 10 minutes in a shaker provided at 180 rpm. The samples were then filtered into new sets of plastic vials and filtered using Whatman paper number 2. The solutions were then analyzed for the exchangeable K, Ca, Mg, and Na using the Atomic Absorption Spectrophotometry (AAS).

3.2.5 Cation Exchange Capacity (CEC) Determination

Cation exchange capacity (CEC) of the soil samples was determined using the ammonium acetate (leaching) method (Cottenie, 1980). Ten gram of each soil samples were weighed into leaching tubes covered with broth at the base and Whatman filter paper number 2 at both ends. The soil samples were leached with 1 M NH_4OAc for 5 to 6 hours. The samples were then washed with 95 % of ethanol and the ethanol discarded after collection.

The soils were then leached with 100 mL of 0.1 M K_2SO_4 and the leachate were then collected in 100 mL volumetric and made up to volume. Ten mL of the samples were pipetted into distillation apparatus while 10 mL of 30 % NaOH were added. Distillates were distilled and collected in 10 mL of 2 % boric acid-indicator solution until 50 mL conical flask containing the distillate became twice of the original volume (20 mL) were obtained. The colour changed from purple to green during distillation. The distillates were then titrated with 0.01 M HCl and the colour changed from green to purple.

3.3 Fertilizer Rate

Christmas Island Rock Phosphate (36 % P_2O_5), urea (46 % N) and Muriate of Potash (60 % K_2O) were the three types of fertilizers used in this experiment. The fertilizer N, P, and K rates as shown in Table 1 were used for the MR 220 variety that was recommended by Muda Agricultural Development Authority (MADA) in year 2000 while the fertilizer rate of 90 N kg/ha, 40 P kg/ha and 30 K kg/ha was that recommended by Semengok Agriculture Research Centre (ARC) Kuching Sarawak in 2006 was used for the ARC 2 variety. The details of the split fertilizer application for both varieties are presented in Tables 1 and 2.

Table 1: Split fertilizer application for MR 220 variety

DAS	Fertilizer Application	Rate/ Amount
15	I (At 3 leaf stage)	Mixed fertilizer 17.5 kg N:15.5 kg P_2O_5:10kg K_2O for 100 kg fertilizer (360kg /ha)
35-40	II (At midtillering)	Urea (46%) 100 kg/ha
50-55	III (Panicle initiation)	Top dressing 12:12:17:2MgO + TE

Table 2: Split fertilizer application for ARC 2 variety

Application	DAS
1st application (1/3)	20-25
2nd application (1/3)	45-55

The ARC 2 plants were monitored for 65 days while MR 220 plants were monitored for 70 days. The soil samples for ARC 2 were taken after 65 days while that of MR 220 were taken after 70 days and both of the soils analyzed for N, K, Ca, Mg, Na, organic matter, pH, and CEC. The N and K uptake of the varieties were also determined. At 65 and 70 days after planting, the plants were harvested and partitioned into roots and stems. Standard procedures were used to dry these parts and determination of their dry weight.

3.4 Soil and Plants Analysis after Planting.

3.4.1 Determination of K, Ca, Mg, and Na in Plant

Dry ashing (single dry ashing) (Cottenie, 1980) was adopted for the extraction of K, Ca, Mg, and Na in plant tissues. Some samples of plant parts were initially oven dried for 24 hours at a temperature of 60 °C after which they were cooled in a desicator and 0.5 g weighed into crucible and placed in a muffle furnace and initially ashed at 300 °C for 1 hour and the temperature was raised to 520 °C for 4-5 hours.

Few drops of distilled water were added to the samples, followed by 2 mL concentrated HCl. Samples were evaporated to dryness in a fume chamber. Ten mL of 20 % HNO_3 was added to the samples and heated on a hot plate in a fume chamber for 1 hour. The samples were filtered through Whatman filter paper number 2 into volumetric flask of 100 mL and diluted to volume. The solutions were analyzed for K, Ca, Mg, and Na using AAS.

3.4.2 Nitrogen, and K Use Efficiency

The concentrations of N and K in the plant parts multiplied by their dry matter gave the amount of N and K taken up by the plant parts. Nitrogen and K use-efficiency was calculated using the subtraction method. Nitrogen and K use efficiency was calculated using the formula:

Example:

% N use efficiency

$$= \frac{\text{Total N uptake in fertilized plots - Total N uptake in unfertilized plots}}{\text{Total amount of N fertilizer applied}} \times 100\%$$

(Pomares-Gracia and Pratt, 1987)

3.5 Experimental Design and Statistical Analysis

The study was t-test (paired and unpaired) in a Completely Randomized Design with 6 replications. The data were analyzed statistically by independent and paired t-test to detect treatment effect for the treatment with and without fertilizer for both MR 220 and ARC 2. The statistical software used was the Statistical Analysis System (SAS) version 9.1 (SAS, 2001).

CHAPTER 4

RESULTS

4.1 Physical and Chemical Properties of Bekenu Series

The chemical and physical properties of Bekenu series was done to get information on pH, CEC, N, K, Ca, Mg, and bulk density before and after planting. The physical and chemical properties of Bekenu series before planting are shown in (Table 3). The bulk density of the Bekenu series was 1.25 g/cm^3. The pH of the soil was 4.78 in water while for pH in 1 N KCl it was 4.08. The average value for the CEC before planting was 10.7 cmol(+)/kg soil. The total N, exchangeable K, Ca, and Mg were 0.25 %, 6.82 mg/kg, 7.24 mg/kg, and 35.36 mg/kg respectively. These information were typical of Bekenu series.

Table 3: Physical and chemical properties of Bekenu series before planting

Bulk Density g/cm^3	pH (Water)	pH (KCl)	CEC cmol(+)/kg soil	N %	K	Ca mg/kg	Mg
1.25	4.78	4.08	10.7	0.25	6.82	7.24	35.36

The treatment mean of the CEC after planting for MR 220 without fertilizer (T0) was 17.60 cmol(+)/kg while that of with fertilizer (T1) was 14.40 cmol(+)/kg. For ARC 2, the CEC of T0 was 17.78 cmol(+)/kg while that of T1 was 12.03 cmol(+)/kg. The pH in KCl, of T0 was 3.95 while that of T1 was 4.18. For the pH in water, the treatment mean of T0 for MR 220 was 4.68 while that of T1 was 4.95. For ARC 2, the pH values of T0 and T1 were 5.42 and 5.52 respectively.

The results of the statistical comparisons of the treatment means for CEC, and pH (in KCl and water) of the Bekenu soil after harvest under fertilized and unfertilized conditions are presented in Table 4. The comparisons (Table 4) were: (i) CEC of T0 and T1 for both varieties – no significant difference, (ii) pH (KCl) of T0 and T1 – significant difference and, (iii) pH (water) of T0 and T1 – significant difference under MR 220 cultivation. There was no significant difference between the CEC and pH (water and KCl) of T0 and T1 for ARC 2.

Soil total N, exchangeable K, Ca, Mg, and Na under with and without fertilizer are shown in Table 4. The total N of T0 and T1 were 0.33 and 0.34 % for MR 220 while that for T0 and T1 of ARC 2 were 0.31 and 0.32 %. The means of (under MR 220 cultivation) T0 for K, Ca, Mg, and Na were 20.91, 26.77, 18.50, and 22.21 mg/kg respectively while that of T1 for K, Ca, Mg, and Na were 54.63, 38.10, 18.55 and 23.06 mg/kg respectively. In the case of ARC 2, the means of K, Ca, Mg, and Na under T0 were 20.52, 24.17, 18.87, and 21.93 mg/kg respectively while that of T1 for K, Ca, Mg, and Na were 48.50, 33.25, 19.79 and 25.13 mg/kg, respectively.

The statistical comparisons of the treatment means shown in Table 4 for MR 220 were: (i) Total N of T0 and T1 – no significant difference, (ii) Exchangeable K of T0 and T1 – significant difference, (iii) Exchangeable Ca of T0 and T1 – no significant difference, (iv) Exchangeable Mg of T0 and T1 – no significant difference, and (v) Exchangeable Na of T0 and T1 – no significant difference. Similar observation was found for ARC 2.

Table 4: Chemical properties of Bekenu series after planting

Variety	Treatment	pH		CEC	Total Nitrogen	K	Ca	Mg	Na
		KCl	Water						
				cmol (+)/kg soil	%	mg/kg			
MR 220	T0	3.95[a]	4.68[a]	17.60[a]	0.33[a]	20.91[a]	26.77[a]	18.50[a]	22.21[a]
	T1	4.18[b]	4.95[b]	14.40[a]	0.34[a]	54.63[b]	38.10[a]	18.55[a]	23.06[a]
ARC 2	T0	4.51[a]	5.42[a]	17.78[a]	0.32[a]	20.52[a]	24.17[a]	18.87[a]	21.93[a]
	T1	4.57[a]	5.52[a]	12.03[a]	0.31[a]	48.50[b]	33.25[a]	19.79[a]	25.13[a]

Note: Means within column for each variety with same superscript are not significantly different at $P \leq 0.05$ (independent t-test)

4.2 Height of the plant

The average heights of MR 220 and ARC 2 are presented in Figures 1 and 2. The average height for MR 220 of T0 in ascending order (Day 15 to Day 60) was 25.89, 36.38, 35.47 and 36.50 cm while that of T1 was in the order of 25.28, 36.64, 37.58 and 38.02 cm. In the case of ARC 2 the order for T0 was 22.40, 34.93, 36.47 and 37.41 cm while that of T1 was 23.08, 30.10, 36.26 and 36.88 cm. There was no significant difference in the heights of both varieties regardless of treatment (T0 and T1).

a) MR 220 Variety

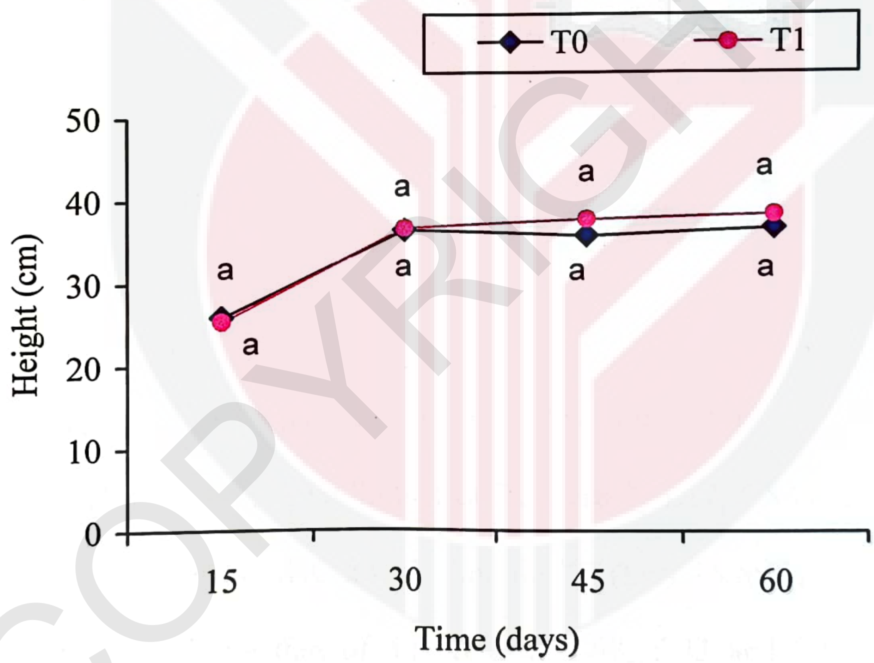

Figure 1: Effect of T0 and T1 on height of MR 220 with time

Note: Means with same alphabet indicate no significant difference between treatments by paired t-test at $p \leq 0.05$.

b) ARC 2 Variety

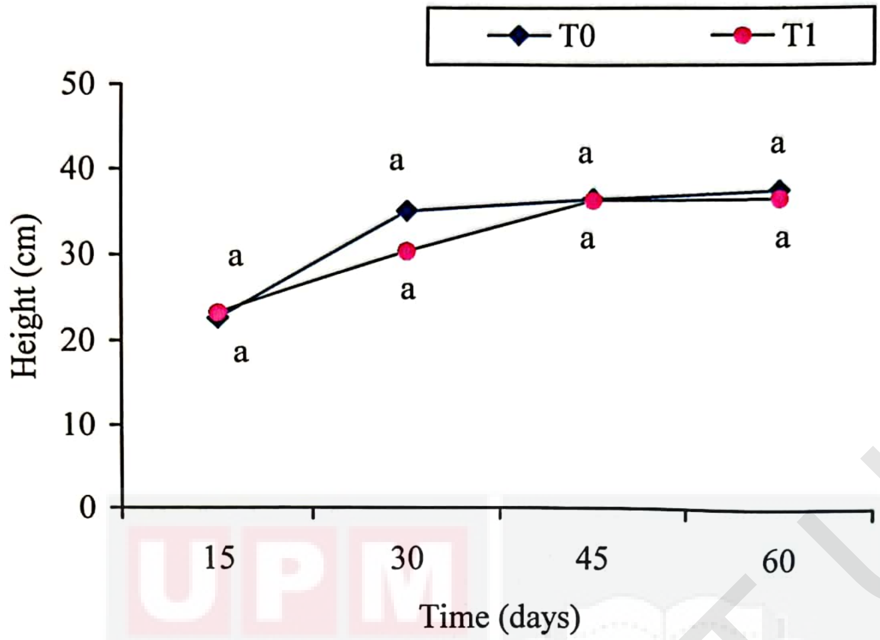

Figure 2: Effect of T0 and T1 on height of ARC 2 with time

Note: Means with same alphabet indicate no significant difference between treatments by paired t-test at $p \leq 0.05$.

4.3 Total Panicle

The average number of panicles of MR 220 with time for T0 (Day 15 to Day 60) were 3, 5.17, 5.17 and 5, while that of T1 were 3, 5.17, 5.83 and 7. The average number of panicles of ARC 2 with time for T0 (Day 15 to Day 60) were 3, 5.67, 6.17, and 5.67, while that of T1 were 3, 5.67, 5.33 and 5.83. There was no significant difference between treatments (T0 and T1) for both varieties (Figures 3 and 4).

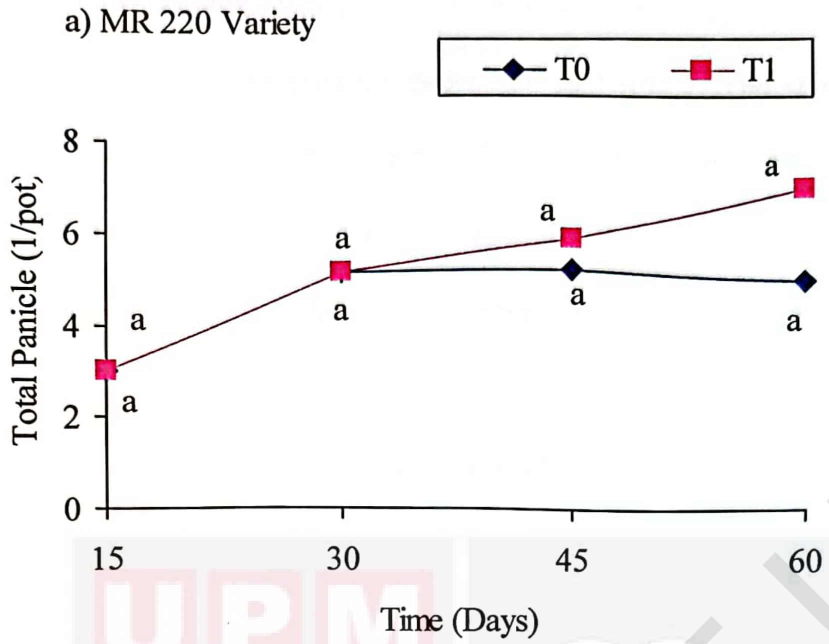

Figure 3: Effect of T0 and T1 on total number of panicles of MR 220 with time

Note: Means with same alphabet indicate no significant difference between treatments by paired t-test at p≤ 0.05.

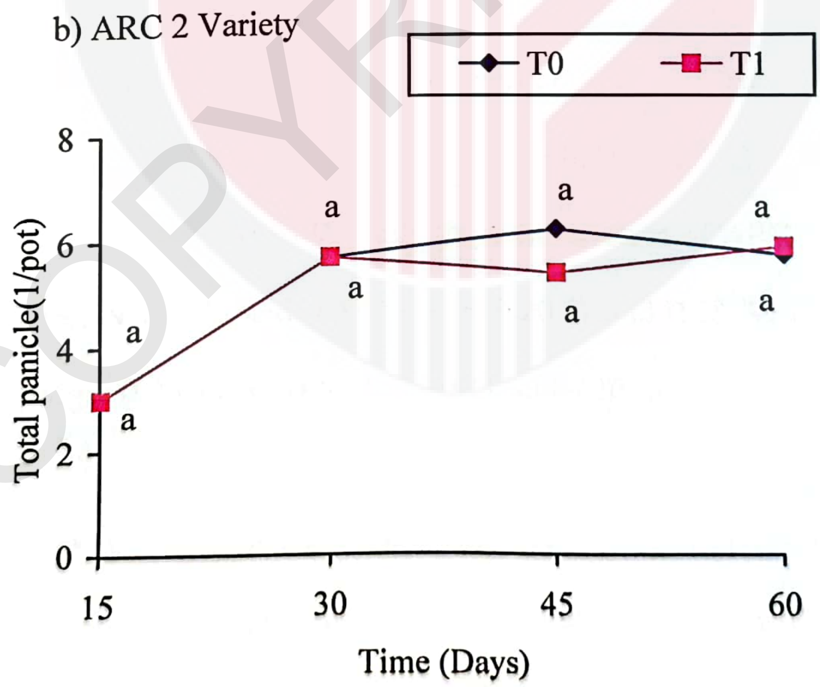

Figure 4: Effect of T0 and T1 on total number of panicles of ARC 2 with time

Note: Means with same alphabet indicate no significant difference between treatments by paired t-test at p≤ 0.05.

4.4 Plants Dry Weight

The results of the dry weights are presented in Table 5. The stem and roots dry weights of T0 and T1 were 5.39 and 5.25 g respectively for MR 220 while that of ARC 2 for T0 and T1 were 3.15 (stem) and 1.83 g (roots). For both varieties, only the root dry weight of ARC 2 was significantly different (Table 5).

4.5 Nutrient Concentrations in Stem and Root

Nitrogen, K, Ca, Mg, and Na concentrations in stems and roots of MR 220 and ARC 2 are presented in Table 5. The concentrations in the stem of MR 220 for T0 and T1 were: N = 1.14 and 2.33 %; K = 1.73 and 1.11 %; Ca = 0.15 and 0.10 %; Mg = 0.05 and 0.06 %; Na = 0.13 and 0.10 % while those in the stem of ARC 2 for T0 and T1 were: N = 0.61 and 0.42 %; K = 1.70 % and 1.71 %; Ca = 0.17 and 0.14 %; Mg = 0.0002 and 0.0022 %; Na = 0.13 and 0.11 %.

For the roots of MR 220, the nutrient concentrations for T0 and T1 were: N = 0.63 and 1.19 %; K = 0.16 and 0.23 %; Ca = 0.01 and 0.03 %; Mg = 0.04 and 0.03 %; Na = 0.11 and 0.10 % while those in the stem of ARC 2 for T0 and T1 variety were: N = 1.28 and 0.93 %; K = 0.20 % and 0.18 %; Ca = 0.0067 and 0.007 %; Mg = 0.26 and 0.04 %; Na = 0.11 and 0.10 %.

The outcome of the statistical comparisons for MR 220 (Table 5) were: (i) T0 and T1 – no significant difference in dry weight (DW), Mg, and Na concentrations in stems but there was significant difference in N, K and Ca concentrations, and (ii) no significant difference in dry weight (DW), K, Ca, Mg and Na concentrations but there was significant difference only for N concentration in roots. In the case of roots, there was no significant difference in dry weight (DW), K, Ca, Na, and Mg of T0 and T1; however, there was significant difference for N. For ARC 2, the following were observed: (i) T0 and T1 – no significant difference in dry weight (DW), N, K, Ca, and Mg concentrations in stems but only significant difference for Na, and (ii) significant difference in only root dry weight.

Table 5: Effect of T0 and T1 on Dry weight (DW) and N, K, Ca, Mg, and Na concentrations of MR 220 and ARC 2

N		MR 220						ARC 2					
Parts	Treatment	DW	N	K	Ca	Mg	Na	DW	N	K	Ca	Mg	Na
		(g)			%			(g)			%		
Stems	T0	2.11[a]	1.14[a]	1.73[a]	0.15[a]	0.05[a]	0.13[a]	1.25[a]	0.61[a]	1.70[a]	0.17[a]	0.0002[a]	0.13[a]
	T1	3.28[a]	2.33[b]	1.11[b]	0.10[b]	0.06[a]	0.10[a]	1.90[a]	0.42[a]	1.71[a]	0.14[a]	0.0022[a]	0.11[b]
Roots	T0	2.58[a]	0.63[a]	0.16[a]	0.01[a]	0.04[a]	0.11[a]	0.64[a]	1.28[a]	0.20[a]	0.0067[a]	0.26[a]	0.11[a]
	T1	2.67[a]	1.19[b]	0.23[a]	0.03[a]	0.03[a]	0.10[a]	1.19[b]	0.93[a]	0.18[a]	0.0070[a]	0.04[b]	0.10[a]

Note: Means within column for each variety with same superscript are not significantly different at $P \leq 0.05$ (independent t-test)

4.6 Nutrient Uptake of MR 220 and ARC 2

Table 6 shows the effect of treatments on the uptake of N, K, Ca, Mg, and Na by MR 220 and ARC 2. For stem (MR 220), the treatment means of T0 for N, K, Ca, Mg, and Na were 0.04, 0.04, 0.0032, 0.0009, and 0.0027 g respectively while that of T1 for N, K, Ca, Mg, and Na uptake were 0.17, 0.08, 0.0032, 0.002, and 0.0054 g respectively. For stem (ARC 2), the treatment means of T0 for N, K, Ca, Mg, and Na uptake were 0.008 g, 0.02 g, 0.0021 g, 0.025 mg, and 0.0016 g respectively while that of T1 for N, K, Ca, Mg, and Na uptake were 0.010 g, 0.03 g, 0.0027 g, 0.042 mg, and 0.0021 g respectively.

For roots of MR 220, N, K, Ca, and Na uptake for T0 were 0.02, 0.004, 0.0002, 0.0009, and 0.0028 g respectively, while that of T1 for N, K, Ca, Mg, and Na uptake were 0.07, 0.006, 0.0016, 0.0009, and 0.0025 g respectively. The treatments means in roots (ARC 2) of T0 for N, K, Ca, Mg, and Na uptake were 0.009 g, 0.001 g, 0.043 mg, 0.0015 g, and 0.0007 g respectively while that of T1 for N, K, Ca, Mg, and Na uptake were 0.027 g, 0.002 g, 0.083 mg, 0.0005 g, and 0.0012 g respectively.

The result of the statistical comparison of the treatment means are presented in Table 6. The comparisons for MR 220 were: (i) Nutrients uptake by stem without (T0) No significant difference in K, Ca, Mg and Na uptake, and (ii) No significant difference in N, K, Ca, Mg and Na. Under (T0) and (T1) for ARC 2, there were no significant differences in N, K, Ca, Mg, and Na in stem and roots.

Table 6: Effect of T0 and TI on the uptake of N, K, Ca, Mg, and Na of MR 220 and ARC 2

Parts	Treatment	MR 220					ARC 2				
		N	K	Ca	Mg	Na	N	K	Ca	Mg	Na
				(g)					(g)		
Stems	T0	0.04[a]	0.04[a]	0.003[a]	0.0009[a]	0.002[a]	0.008[a]	0.02[a]	0.0021[a]	*0.025[a]	0.0016[a]
	T1	0.17[b]	0.08[a]	0.003[a]	0.002[a]	0.005[a]	0.010[a]	0.03[a]	0.0027[a]	*0.042[a]	0.0021[a]
Roots	T0	0.02[a]	0.004[a]	0.0002[a]	0.0009[a]	0.0028[a]	0.009[a]	0.001[a]	*0.043[a]	0.0015[a]	0.0007[a]
	T1	0.07[a]	0.006[a]	0.0016[a]	0.0009[a]	0.0025[a]	0.027[a]	0.002[a]	*0.083[a]	0.0005[a]	0.0012[a]

Note: Means within column for each variety with same superscript are not significantly different at $P \leq 0.05$ (independent t-test)

Note: *Mg and Ca uptake are in mg.

4.5 Nitrogen and K Use Efficiency

The results of N and K use efficiency in paddy (stem and roots) are shown in Table 7. For stem of MR 220, the N and K use efficiencies were 3.25 and 3.65 %, respectively while those of roots were 1.25 and 0.18 %. In the case of stem of ARC 2, they were 0.15 and 1.25 % for N and K respectively while those of the roots were 1.38 and 0.13 % for N and K respectively. This shows that the efficiency of N and K in stem was higher compare to roots. The overall N and K use efficiencies for variety MR 220 were 4.50 and 3.83 % respectively. For ARC 2, the overall N and K use efficiencies were 1.53 and 1.38 % respectively. These show that both of the varieties took more N compared to K. Regardless of treatment, the low percentages of N and K indicate that the N and K nutrient uptake by the plants was inefficient on Bekenu series.

Table 7: Nitrogen and K use efficiency of MR 220 and ARC 2

	Variety MR 220			Variety ARC 2	
Treatments	N	K	Treatments	N	K
	%			%	
Stems	3.25	3.65	Stems	0.15	1.25
Roots	1.25	0.18	Roots	1.38	0.13
Total	4.50	3.83		1.53	1.38

CHAPTER 5

DISCUSSION

The insignificant difference between the CEC of T0 and T1 at harvest suggests that fertilization did not affect the exchange property of the soil within the time frame of this study (Table 4). This observation was expected as organic matter that usually affects soil CEC was not included in this study and no leaf decomposition in the experimental pots as the plants were growing. However, the pH of T1 in both water and KCl were greater than those of T0 (Table 4) probably due to the addition of fertilizers particularly urea which is noted for increasing soil pH rapidly at the soil microsites (Ahmed *et al.,* 2006). Anhydrous ammonia, urea, diammonium phosphate, and nitrogen solutions, when first applied, greatly but temporarily increase soil pH in the zone of application (Wilson et *al.,* 2001).

The significant increase in soil exchangeable K concentration (Table 4) for T1 could be because of the addition KCl. This finding was consistent with that of Nand (2000) who observed that the patterns of the availability of K were affected by continuous fertilizer use. Concentrations of Ca, Mg, and Na were not significantly different perhaps there was not much of these elements in the fertilizers applied.

The general lack significant difference in plant height and total number of panicles irrespective of treatment and rice variety (Figures 1, 2, 3, and 4) suggests that these variables did not respond to fertilization within the time frame of this study. This observation might have reflected in the dry matter production as with the exception of roots of ARC 2 where the dry weight of T1 was significantly higher than that of T0, the dry matter production of both MR 220 and ARC 2 were similar under the fertilized and unfertilized conditions (Table 5).

The significant increase in N and K in the stem of MR 220 may be because of the application of urea and KCl but the insignificant difference in nutrient concentrations in the roots of MR 220 and both roots and stem of ARC 2 (Table 5) could be associated with dilution effect (Marschner, 1995; Mengel and Kirby, 1996). The general lack of significant effect on N and K uptake may be partly due to ammonia volatilization and denitrification under reduced condition or under submerged conditions of rice (Prasertsak *et al.,* 2001; Cai *et al.,* 2002). Upon application, urea-N changes rapidly to NH_4-N and therefore is readily available to plants on application to the soil. Urea presents another problem, in that when it is surface-applied, significant quantities of N as ammonia may be lost through volatilization which cause low N uptake in plants (Prasertsak *et al.,* 2001; Cai *et al.,* 2002). This occurs because the urea dissolves, be in contact with the soil for conversion to volatile N, and easily escapes to the atmosphere due to its proximity to the soil surface (Nambiar, 1994; Prasertsak *et al.,* 2001; Cai *et al.,* 2002).

For no apparent reason lack of K response upon fertilization could not be properly explained but it is believed that K response in some Malaysian soils is poor. It must however, be stressed that aforementioned observation on the lack of significant K response seems to be consistent with the findings of Embi and Shuhaimen (1980). In their field trials conducted on a wide range of soil conditions in Kemubu from 1973-1978, the workers found that K did not increase grain yields even when the other major nutrients were high. In addition, analysis of K content in the straw and grain samples did not exhibit any deficiency trend even in the control plots (without fertilizer).

Regardless of treatment, the low percentages of N and K indicate that the N and K nutrient use by MR 220 and ARC 2 on Bekenu series was low. The low fertility status and the terrain on which these soils occur could be some of the limiting factors for the use of these soils. However, with proper addition of organic fertilizers as supplement of inorganic fertilizers and soil conservation measures, the N and K use efficiency may be improved.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

Application of K fertilizer significantly increased soil exchangeable K under MR 220 and ARC 2 cultivations. But this accumulation did not reflect in significant plant growth (height and number of panicles), dry matter production, K uptake and K use efficiency. Urea application significantly increased N concentration in both roots and stem of MR 220 but significant effect of the N fertilizer reflected in stem only. Urea application however, did not affect N accumulation, plant height, number of panicles, and dry matter production. Nitrogen use efficiency was also low. As the results showed inefficient nutrient use, series of trials on Bekenu series on the interaction between inorganic and organic fertilizers (e.g. compost) should be carried out as this is likely to improve the inherent low exchange properties of this soil that partly contributes to poor fertility properties.

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APPENDICES

Appendix A: Selected chemical and physical properties of Bekenu series before planting

	Bulk Density g/cm^3	pH Water	pH KCl	CEC cmol(+)/kg soil	N %	K mg/kg	Ca mg/kg	Mg mg/kg
1	0.00	5.00	3.90	12.00	0.28	4.14	6.86	33.30
2	0.00	4.90	4.10	13.00	0.28	6.30	13.27	45.40
3	1.32	4.60	4.00	13.00	0.28	5.91	4.64	38.00
4	0.00	4.70	4.00	12.00	0.28	6.41	3.05	34.10
5	1.12	4.80	4.10	12.00	0.28	5.09	1.97	24.30
6	1.03	4.90	4.10	7.00	0.14	4.86	1.71	29.20
7	1.38	4.40	3.80	6.00	0.14	7.75	1.93	28.30
8	1.31	4.40	3.80	6.00	0.28	8.48	2.23	32.50
9	1.29	4.80	4.10	12.00	0.28	8.42	23.22	54.20
10	1.32	5.30	4.90	14.00	0.28	10.86	13.50	34.30
Average	1.25	4.78	4.08	10.7	0.25	6.82	7.24	35.36

Appendix B1: Selected chemical properties of Bekenu series after planting MR 220

	pH Kcl	pH Water	CEC	Total Nitrogen	K	Ca	Mg	Na
			cmol (+)/kg soil	%	mg/kg	mg/kg	mg/kg	mg/kg
T0R1	4.04	4.75	17.00	0.423	17.19	22.34	16.12	17.86
T0R2	3.92	4.66	16.50	0.331	13.92	12.46	15.45	14.62
T0R3	3.98	4.83	7.80	0.303	20.20	23.80	18.57	19.85
T0R4	3.92	4.56	15.50	0.370	14.27	23.48	19.00	17.06
T0R5	3.96	4.65	14.20	0.294	29.94	36.72	20.37	18.34
T0R6	3.9	4.61	34.60	0.286	29.91	41.84	21.46	45.52
T1R1	4.18	4.86	8.50	0.350	45.16	37.90	18.39	24.56
T1R2	4.24	4.79	21.00	0.381	72.16	53.68	20.14	40.84
T1R3	4.18	5.04	12.80	0.353	46.08	27.15	17.00	16.88
T1R4	4.28	5.02	17.00	0.297	66.26	57.16	20.14	23.36
T1R5	4.15	5.07	13.00	0.336	51.64	26.10	17.84	18.29
T1R6	4.07	4.94	14.10	0.322	46.48	26.62	17.79	14.41

Appendix B2: Selected chemical properties of Bekenu series after Planting ARC 2

	pH Kcl	pH Water	CEC	Total Nitrogen	K	Ca	Mg	Na
			cmol (+)/kg soil	%	mg/kg	mg/kg	mg/kg	mg/kg
T0R1	4.48	5.38	52.50	0.319	27.24	19.92	19.01	22.74
T0R2	4.68	5.50	15.70	0.328	24.40	50.80	20.43	23.07
T0R3	4.49	5.38	23.70	0.336	18.09	21.93	18.51	25.98
T0R4	4.49	5.61	13.40	0.300	18.54	14.82	18.02	19.92
T0R5	4.43	5.29	0.80	0.291	15.74	13.74	17.11	19.12
T0R6	4.48	5.35	0.60	0.322	19.12	23.80	20.13	20.77
T1R1	4.74	5.72	16.20	0.314	53.16	46.80	20.28	21.16
T1R2	4.73	5.65	12.00	0.269	56.40	62.44	21.18	39.63
T1R3	4.47	5.36	10.70	0.359	42.40	25.37	19.63	16.90
T1R4	4.40	5.22	18.00	0.269	43.48	19.66	19.20	26.03
T1R5	4.52	5.50	14.60	0.325	45.36	21.66	18.96	25.35
T1R6	4.58	5.66	0.70	0.317	50.20	23.54	19.51	21.68

Appendix C1: Height and total number of panicles of MR 220

	DAYS							
	15		30		45		60	
	Height	Total Panicle	Height	Total panicle	Height	Total panicle	Height	Total panicle
T0R1	26.42	3	36.11	6	36.31	5	37.37	5
T0R2	25.13	3	31.46	5	32.19	5	31.84	5
T0R3	22.08	3	33.24	5	33.90	6	34.87	5
T0R4	26.33	3	35.71	5	37.27	5	39.71	5
T0R5	28.86	3	35.03	5	35.60	5	35.84	5
T0R6	26.53	3	35.44	5	37.54	5	39.36	5
T1R1	25.49	3	36.56	6	44.30	9	45.86	13
T1R2	26.53	3	35.74	5	37.84	5	37.90	5
T1R3	26.24	3	36.11	5	36.86	6	37.00	7
T1R4	21.33	3	35.74	5	35.79	5	36.04	5
T1R5	25.54	3	33.26	5	33.94	5	33.77	6
T1R6	26.56	3	35.11	5	36.76	5	37.53	6

Appendix C2: Height and total number of panicles of ARC 2

	DAYS							
	15		30		45		60	
	Height	Total panicle	Height	Total panicle	Height	Total panicle	Height	Total panicle
T0R1	24.06	3	35.07	5	35.23	5	35.50	6
T0R2	21.91	3	35.73	5	36.69	5	37.73	6
T0R3	23.11	3	36.24	5	35.91	7	36.33	5
T0R4	22.43	3	35.56	6	37.71	7	40.53	6
T0R5	21.5	3	33.96	6	37.53	7	36.73	5
T0R6	21.37	3	32.99	7	35.77	6	37.61	6
T1R1	25.64	3	36.53	6	38.91	5	42.93	8
T1R2	27.13	3	32.99	6	35.59	6	35.89	5
T1R3	24.59	3	36.17	6	36.43	5	36.36	6
T1R4	17.77	3	34.74	5	35.71	5	35.83	5
T1R5	22.34	3	33.93	5	34.00	5	34.26	6
T1R6	21.00	3	36.00	6	36.89	6	36.01	5

Appendix D1: Dry Weight (DW) and N, K, Ca, Mg, Na concentrations in stems of paddy plants

Parts		The concentrations for MR 220						The concentrations for ARC 2					
		DW	N	K	Ca	Mg	Na	DW	N	K	Ca	Mg	Na
		(g)			%			(g)			%		
Stems	T0R1	2.32	1.4290	1.806	0.172	0.076	0.131	0.85	0.5604	1.627	0.159	0.000	0.143
	T0R2	1.20	1.0930	1.637	0.145	0.076	0.115	1.27	0.2802	1.709	0.206	0.000	0.132
	T0R3	1.84	1.0930	1.659	0.142	0.056	0.124	1.07	0.5604	1.618	0.178	0.001	0.133
	T0R4	2.44	0.7570	1.811	0.122	0.038	0.084	1.73	0.8406	1.921	0.159	0.000	0.124
	T0R5	1.65	1.0370	1.769	0.164	0.029	0.129	1.20	0.5604	1.751	0.170	0.000	0.126
	T0R6	3.21	1.4570	1.714	0.153	0.002	0.171	1.35	0.8406	1.574	0.158	0.000	0.125
	T1R1	7.80	2.1580	1.582	0.094	0.063	0.107	3.80	0.8406	1.930	0.160	0.000	0.108
	T1R2	3.03	3.0820	1.714	0.104	0.069	0.102	1.51	0.5604	1.249	0.046	0.000	0.103
	T1R3	2.47	1.4570	1.053	0.112	0.059	0.094	1.51	0.2802	1.867	0.139	0.004	0.114
	T1R4	1.69	2.7460	0.226	0.103	0.055	0.084	1.55	0.2802	1.853	0.191	0.001	0.107
	T1R5	1.55	3.7270	0.908	0.094	0.053	0.099	1.53	0.2802	2.022	0.135	0.007	0.111
	T1R6	3.16	0.8130	1.156	0.081	0.053	0.095	1.47	0.2802	1.366	0.160	0.001	0.110

Appendix D2: Dry Weight (DW) and N, K, Ca, Mg, Na concentrations in roots of paddy plants

		The concentrations for MR 220						The concentrations for ARC 2					
Parts		DW	N	K	Ca	Mg	Na	DW	N	K	Ca	Mg	Na
		(g)			%			(g)			%		
Roots	T0R1	3.02	0.9530	0.234	0.010	0.040	0.123	0.19	1.4010	0.253	0.007	0.443	0.119
	T0R2	1.53	1.0930	0.286	0.007	0.033	0.091	0.66	1.4010	0.089	0.005	0.251	0.060
	T0R3	2.54	0.4480	0.103	0.008	0.030	0.079	0.55	0.7005	0.139	0.006	0.331	0.136
	T0R4	2.62	0.3640	0.145	0.008	0.034	0.081	0.95	2.1015	0.281	0.005	0.459	0.150
	T0R5	1.93	0.5040	0.101	0.011	0.044	0.140	0.71	1.4010	0.284	0.009	0.045	0.130
	T0R6	3.81	0.3920	0.109	0.006	0.035	0.123	0.76	0.7005	0.154	0.008	0.034	0.090
	T1R1	7.40	1.7090	0.234	0.108	0.037	0.104	1.91	1.4010	0.254	0.014	0.042	0.096
	T1R2	2.09	1.0090	0.168	0.009	0.032	0.108	0.73	0.7005	0.116	0.008	0.035	0.098
	T1R3	1.86	1.2050	0.152	0.048	0.028	0.079	0.77	1.4010	0.224	0.004	0.042	0.115
	T1R4	1.43	1.7370	0.279	0.009	0.034	0.094	1.47	0.7005	0.193	0.004	0.040	0.101
	T1R5	1.06	1.1490	0.342	0.010	0.026	0.080	0.81	0.7005	0.122	0.005	0.031	0.073
	T1R6	2.19	0.3080	0.216	0.006	0.027	0.073	1.43	0.7005	0.164	0.007	0.040	0.101

Appendix E1: Dry Weight (DW) and N, K, Ca, Mg, Na uptake in stems of paddy plants

		Nutrient uptake MR 220						Nutrient uptake ARC 2					
Parts		DW (g)	N	K	Ca (g)	Mg	Na	DW (g)	N	K	Ca (g)	Mg	Na
Stems	T0R1	2.32	0.03315	0.04190	0.00399	0.00176	0.00304	0.85	0.00476	0.01383	0.00135	0.000000	0.00122
	T0R2	1.20	0.01312	0.01964	0.00174	0.00091	0.00138	1.27	0.00355	0.02170	0.00262	0.000000	0.00168
	T0R3	1.84	0.02011	0.03053	0.00261	0.00103	0.00228	1.07	0.00600	0.01731	0.00190	0.000005	0.00142
	T0R4	2.44	0.01847	0.04419	0.00298	0.00093	0.00205	1.73	0.01454	0.03323	0.00275	0.000007	0.00215
	T0R5	1.65	0.01711	0.02919	0.00271	0.00048	0.00213	1.20	0.00672	0.02101	0.00204	0.000001	0.00151
	T0R6	3.21	0.04677	0.05502	0.00491	0.00006	0.00549	1.35	0.01135	0.02125	0.00213	0.000000	0.00169
	T1R1	7.80	0.16832	0.12340	0.00733	0.00491	0.00835	3.80	0.03194	0.07334	0.00608	0.000000	0.00410
	T1R2	3.03	0.09338	0.05193	0.00315	0.00209	0.00309	1.51	0.00846	0.01886	0.00069	0.000000	0.00156
	T1R3	2.47	0.03599	0.26009	0.00277	0.00146	0.00232	1.51	0.00432	0.02819	0.00210	0.000060	0.00172
	T1R4	1.69	0.04641	0.00382	0.00174	0.00093	0.01420	1.55	0.00434	0.02872	0.00296	0.000023	0.00166
	T1R5	1.55	0.05777	0.01407	0.00146	0.00082	0.00153	1.53	0.00429	0.03094	0.00207	0.000104	0.00170
	T1R6	3.16	0.02569	0.03653	0.00256	0.00167	0.00300	1.47	0.00412	0.02008	0.00235	0.000009	0.00162

Appendix E2: Dry Weight (DW) and N, K, Ca, Mg, Na uptake in roots of paddy plants

Parts		Nutrient uptake MR 220						Nutrient uptake ARC 2					
		DW	N	K	Ca	Mg	Na	DW	N	K	Ca	Mg	Na
		(g)			(g)			(g)			(g)		
Roots	T0R1	3.02	0.0288	0.0070	0.00030	0.00121	0.00371	0.19	0.0027	0.00048	0.000013	0.00084	0.00023
	T0R2	1.53	0.0167	0.0044	0.00011	0.00050	0.00139	0.66	0.0093	0.00059	0.000033	0.00166	0.00040
	T0R3	2.54	0.0114	0.0026	0.00020	0.00076	0.00201	0.55	0.0039	0.00076	0.000033	0.00182	0.00075
	T0R4	2.62	0.0095	0.0038	0.00021	0.00089	0.00212	0.95	0.0200	0.00267	0.000048	0.00436	0.00143
	T0R5	1.93	0.0097	0.0019	0.00021	0.00085	0.00270	0.71	0.0100	0.00202	0.000064	0.00032	0.00092
	T0R6	3.81	0.0149	0.0042	0.00023	0.00133	0.00469	0.76	0.0053	0.00117	0.000061	0.00026	0.00068
	T1R1	7.40	0.1265	0.0173	0.00799	0.00274	0.00770	1.91	0.0268	0.00485	0.000267	0.00080	0.00183
	T1R2	2.09	0.0211	0.0035	0.00019	0.00067	0.00226	0.73	0.0051	0.00085	0.000058	0.00026	0.00072
	T1R3	1.86	0.2241	0.0028	0.00089	0.00052	0.00147	0.77	0.0108	0.00172	0.000031	0.00032	0.00089
	T1R4	1.43	0.0248	0.0040	0.00013	0.00049	0.00134	1.47	0.0103	0.00284	0.000059	0.00059	0.00148
	T1R5	1.06	0.0122	0.0036	0.00011	0.00028	0.00085	0.81	0.0057	0.00099	0.000041	0.00025	0.00059
	T1R6	2.19	0.0068	0.0047	0.00013	0.00059	0.00160	1.43	0.1002	0.00235	0.000100	0.00057	0.00144

PUBLICATION OF THE PROJECT UNDERTAKING

This is to certify that I have no objection to publish the project entitled "Evaluation of Nitrogen and Potassium Uptake and Efficiency of Two Rice Varieties on Bekenu series" by the supervisor in a joint authorship. However, it has to be evaluated by the Faculty of Agriculture and Food Sciences, University Putra Malaysia Bintulu Campus and published in form approved by the Faculty.

SHAJARUTULWARDAH BINTI MOHD YUSOB

07 MAY 2007