

THE INFLUENCE OF SOIL WATER STATUS ON THE PHYSIOLOGY OF *ORYZA SATIVA* VAR. MR220

KESAN STATUS AIR TANAH TERHADAP FISIOLOGI ORYZA SATIVA VAR. MR220

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ABSTRACT

A study to determine the influence of soil water status on the physiology of rice plant *Oryza sativa* var. MR220 after panicle initiation stage was carried out at Ladang Merdeka Mulong Lating in the Kemubu Agricultural Development Authority (KADA) area, Kelantan. Five water management treatments imposed on direct seeded rice were; T1. Continuous flooding, T2. Early flooding up to panicle initiation stage followed by saturated (F55-saturated), T3. Early flooding for the first month followed by saturated (F-30 saturated), T4. Continuous saturated, and T5. Continuous field capacity condition throughout the growth stage. The treatments were arranged in Randomized Complete Block Design (RCBD) with four replicates. In-situ stomatal conductance measurement was carried out at 68 DAS (days after seeding) and the elemental analysis of soil and plant samples was carried out using the Instrumental Neutron Activation Analysis (INAA). Results from this study showed significant differences between treatments for soil moisture content and plant moisture content, but no significance different in leaf stomatal conductance. Rice plant moisture, soil moisture and leaf stomatal conductance showed no interaction. Early flooding up to panicle initiation stage followed by saturated (T2: F55-saturated) resulted in higher plant moisture content. Soil plant transfer coefficient was highest in continuous saturated (T4) for nitrogen, early flooding for the first month followed by saturated (T3: F-30 saturated) for potassium, continuous field capacity condition throughout the growth stage (T5) for magnesium, and continuous flooding (T1) for sodium.

ABSTRAK

Satu kajian untuk menentukan kesan status air tanah terhadap padi *Oryza sativa* var. MR220 selepas peringkat permulaan bulir telah dilaksanakan di Ladang Merdeka Mulong Lating di dalam Kawasan Lembaga Kemajuan Pertanian Kemubu (KADA), Kelantan. Lima perlakuan pengurusan air terhadap padi tabur terus adalah; T1. Pembanjiran berterusan, T2. Pembanjiran awal sehingga ke peringkat permulaan bulir diikuti dengan keadaan tepu (F55-tepu), T3. Pembanjiran awal pada bulan pertama diikuti dengan keadaan tepu (F30-tepu), T4. Keadaan tepu berterusan, dan T5. Keadaan muatan tanah berterusan pada sepanjang peringkat tumbesaran. Perlakuan telah disusun secara Rekabentuk Blok Lengkap Terawak (RBLT) dengan empat replikasi. Pengukuran konduktans stoma daun

dilaksanakan secara *in-situ* pada 68 HSP (*hari selepas penyemaian*) dan analisis unsur-unsur dalam sampel-sampel tanah dan tanaman padi dilaksanakan dengan kaedah Analisis Pengaktifan Neutron Instrumentasi (APNI). Hasil kajian ini menunjukkan perbezaan yang bererti pada kandungan air tanah dan kandungan air tanaman padi tetapi perbezaan yang tidak bererti pada konduktans stoma daun. Perbezaan ketara kandungan air juga didapati di antara replikat dalam urutan $R1 > R2 > R3 > R4$ dan $R2 > R1 > R3 > R4$; pada tanaman padi dan tanah sawah, secara berurutan. Kandungan air padi, kandungan air tanah dan konduktans stoma daun menunjukkan tiada perkaitan. Pemanjiran awal sehingga ke peringkat permulaan bulir diikuti dengan keadaan tepu (F55-tepu) menghasilkan kandungan air tanaman padi yang tinggi. Koefisien pindahan tanah tumbuhan adalah paling tinggi pada keadaan tepu berterusan (T4) untuk nitrogen, pemanjiran awal pada bulan pertama diikuti dengan keadaan tepu (F30-tepu) untuk kalium, keadaan muatan tanah berterusan pada sepanjang peringkat tumbesaran (T5) untuk magnesium, dan pemanjiran berterusan (T1) untuk naterium.

Keywords: Rice *Oryza sativa* var. MR220, soil water status, moisture content, stomatal conductance, soil plant transfer coefficient of mineral nutrient elements.

INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food of Asia. It is a semiaquatic species that is physiologically, morphologically and anatomically adapted to culture in flooded environment. A study to determine the influence of soil water status on rice was carried out in the Kemubu Agricultural Development Authority (KADA) area, Kelantan.

A related previous study on the effect of different water regimes in field experiment at the Ladang Merdeka Mulong Lating, Kemubu Agricultural Development Authority (KADA), Kota Bharu, Kelantan, Malaysia shows that highest yield was obtained from the continuous saturated water regime (T4) treatment in the main season, and continuous flooding until 30 DAS followed by saturation (T2) treatment in the off season (Mohd. Razi et al., 2005). The highest grain yield of 5522 kg/ha was obtained in the main season and 3190 kg/ha in the off season. Overall rice crop yield was lower in this field trials due to sheath blight and panicle blast incidence that occur in KADA area at later stage of rice growing. These results are acceptable because most rice farmers gain less than 60% of the climatic and genetic yield potential at any particular site (Witt et al., 2002).

The irrigation water needs to be continuously supplied during growing period to the KADA area studied and could be a critical limiting factor in causing the yield gaps (Ismail, pers. comm.). The relationship between physiological parameters in *Oryza sativa* var. MR220 with the soil water content under the various water regimes needs to be studied. The objective of this study was therefore to assess the influence of different soil water regimes on physiological parameters of plant moisture content, stomatal conductance and soil plant transfer coefficient (of nutrient elements) in *Oryza sativa* var. MR220; after panicle initiation stage at 68 DAS (days after seeding).

Stomatal conductance is the inverse of stomatal resistance, and the rate of transpiration through diffusion depends on stomatal resistance. Stomatal resistance allows scientist to learn how stomata respond to changes in environmental conditions that include light intensity, humidity and carbon dioxide concentration. In the leaf, stomatal conductance indicates how open or closed the stomata are. The inverse of resistance to diffusion was called permeability, and in the context of gas diffusion it is called conductance (Salisbury and Ross, 1992). The reason for using conductance instead of resistance in this study is that conductance is directly proportional to transpiration rather than inversely proportional.

The soil plant transfer coefficient on the other hand, is the mineral elemental concentration in plant divided by the mineral elemental concentration of soil (Smith, 1996; Henning *et al.*, 2001; Tan *et al.*, 2006; Nashriyah *et al.*, 2006). It was notably used for determining the uptake, transfer and accumulation of nutrients from soil to plant for plant growth. Macronutrients nitrogen (N), phosphorus (P), sodium (S), potassium (K), calcium (Ca), magnesium (Mg) and iron (Fe) are required in large quantities by plant. These essential elements are in greater need of replenishment in agriculture and are normally supplied through fertilizer (Crawford, 1976).

MATERIALS AND METHODS

Study site and treatments

The influence of soil water status on rice plant *Oryza sativa var. MR220* was studied at the Ladang Merdeka Mulong Lating, Kemubu Agricultural Development Authority (KADA), Kota Bharu, Kelantan, Malaysia.

Five water management treatment regimes were imposed on direct seeded rice. The treatments are continuous flooding (T1), early flooding up to panicle initiation stage followed by saturated or F55-saturated (T2), early flooding for the first month followed by saturated or F-30 saturated (T3), continuous saturated (T4), and continuous field capacity condition throughout the growth stage (T5). The treatments were arranged in a Randomized Complete Block Design (RCBD) with four replicates.

Determination of leaf stomatal conductance

Leaf stomatal conductance ($\text{mmol m}^{-2} \text{s}^{-1}$) was measured *in situ* on the abaxial surface of leaf (Mohd. Razi *et al.*, 2005) at up to 30 times per replicate. The measurement was carried out under daylight by using a cycling diffusion Porometer AF-4 (Delta-T Devices Ltd., Cambridge, UK).

Soil sampling and preparation

Soil sampling was carried out at 68 DAS (days after seeding) of rice plant. Soil was sampled using auger at 0-10 cm soil depth. Soil samples were kept in airtight plastic bag under cool temperature prior to transportation to the laboratory for moisture measurement and elemental analysis.

Plant sampling and preparation

Rice plant sampling was carried out at 68 DAS (days after seeding). Plant was carefully pulled out from mud and washed clean from soil in the field. Plant samples were kept in airtight plastic bag under cool temperature prior to transportation to the laboratory for moisture measurement and elemental analysis.

Determination of moisture content in soil and plant

The percentage of moisture in soil or plant sample was determined by drying approximately 2 g of previously weighed wet sample in a ventilation oven at 110 °C overnight or constant weight. Plant moisture content was measured following oven drying at 105 °C for 5 hours until constant weight. Dried soil or plant sample was re-weighed after cooling in a desiccator for at least 10 minutes (Chapman & Pratt, 1961). The moisture content was then calculated by using the following formula:

$$\text{Percent moisture content} = \frac{\text{Loss in weight of the sample}}{\text{Original weight of the sample}} \times 100$$

The results were expressed as the percentage moisture content on a wet weight basis (Bleasdale, 1973).

Analysis of N in soil and plant by using the CHNS Analyzer

Sample was prepared by weighing 2.0 mg dried powder sample in tin capsule, followed by burning of sample at 950 °C and conversion to N₂ gas. Detection of N₂ was carried out by thermal conductivity using the Carbon Hydrogen Nitrogen and Sulfur (CHNS) Analyzer (Nashriyah and Norimah, 2005). Analysis of K, Mg and Na in soil and plant by using the INAA techniques

Analysis of potassium, magnesium and sodium in dried plant and soil samples were carried out using the Instrumental Neutron Activation Analysis (INAA) techniques. Two replicates of 0.15 - 0.20 g oven dried soil or plant powder, and 100 µl of standard solution were each weighed into polyethylene vials and exposed to neutron irradiation in Triga MK-II reactor.

The analysis of short-live radionuclide magnesium requires 1 minute irradiation followed by 20 minutes cooling and 5 minutes counting times. For sodium and potassium radionuclides, irradiation time of 1 minute was followed by 24 hour cooling and 20 minute counting times (Nashriyah *et. al.*, 1996).

Soil plant transfer coefficient of mineral element

Soil plant transfer coefficient or *f* factor was calculated by using the following formula (Smith, 1996; Henning *et. al.*, 2001; Tan *et. al.*, 2006):

$$\text{T.F.} = f \text{ factor} = \frac{[\text{M}]_p}{[\text{M}]_s}$$

Where;

T.F. = Soil plant transfer coefficient

[M]_p = Concentration of mineral element (or metal) in plant (% w/w)

[M]_s = Concentration of mineral element (or metal) in soil (% w/w)

Statistical analysis of data

Statistical analysis of data was carried out by using the SPSS software. Comparisons by applying ANOVA and post hoc test of DUNCAN, were carried out between treatments, between groups and within groups for moisture content of rice plant*treatment, moisture content of soil*treatment, as well as stomatal conductance*treatment.

RESULTS AND DISCUSSION

Soil Moisture Content

Results from this study showed significant differences in soil moisture content in the order of T1>T2>T3>T4>T5 (Table 1). The trends in soil moisture content from each readings taken from all treatments, even though the overall results were significantly different, were demonstrated in Fig. 1.

As expected, continuous flooding (T1) resulted in the highest soil moisture content. Early flooding up to panicle initiation stage followed by saturated or F55-saturated (T2) and early flooding for the first month followed by saturated or F-30 saturated (T3) also effectively increased the moisture content of soil in the ricefield. Moisture content in ricefield soil also showed significant differences between replicates in the order of R2>R1>R3>R4, probably due to uneven ricefield soil surface. High water table was visibly indicated in these treatments by waterlogging in many or some areas within the plot.

Table 1. Soil Moisture Content (%)

	Treatment				
	T1	T2	T3	T4	T5
AVERAGE	37.7	36.0	35.0	33.6	32.6
SD	3.2	4.1	4.3	4.1	3.5
% CV	8.5	11.4	12.3	12.1	10.7

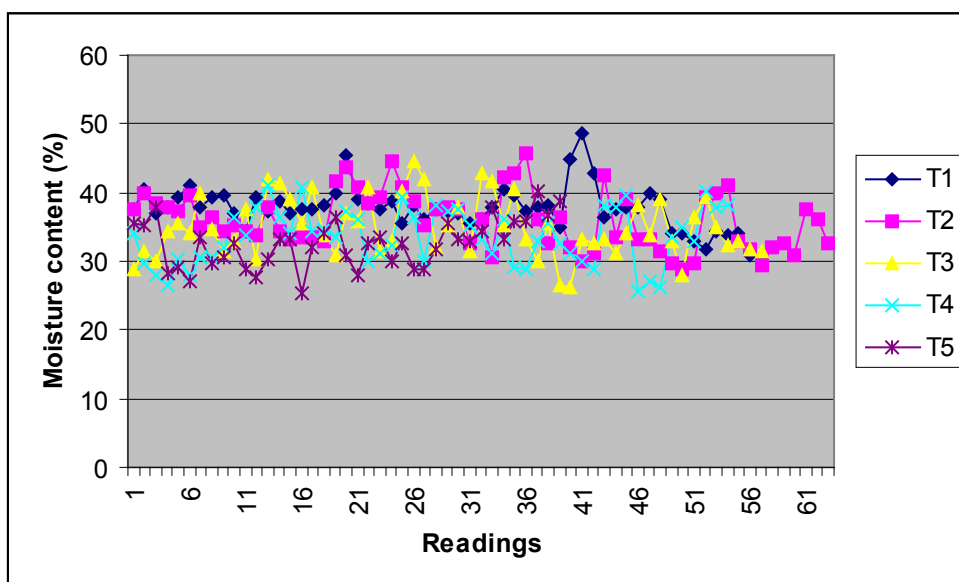


Figure 1: Soil Moisture Content (%)

In summary, results from this study showed significant differences between treatments for soil moisture content at 68 DAS. Soil moisture content was in the order of T1>T2>T3>T4>T5. Moisture content also showed significant differences between replicates in the order of R2>R1>R3>R4, in ricefield soil.

Plant Moisture Content

Significant differences were also observed in rice plant moisture content in the order of T2>T3>T4>T1>T5 (Table 2), the highest value recorded from the early flooding up to panicle initiation stage followed by saturated or F55-saturated (T2) treatment. The treatment where rice plants were exposed to early flooding for the first month followed by saturated or F-30 saturated (T3) also resulted in a high moisture content in the rice plant. Moisture content also showed significant differences between replicates in the order of R1>R2>R3>R4 in the rice plant notably because of unavoidable different sampling days within the sampling week, and probably also due to different periods of storage prior to moisture determination in the laboratory; as shown in high variability of results (Fig. 2).

Table 2. Plant Moisture Content (%)

	Treatment				
	T1	T2	T3	T4	T5
AVERAGE	75.0	78.1	77.3	75.2	73.5
SD	5.7	3.7	3.3	5.5	5.4
% CV	7.7	4.8	4.2	7.3	7.3

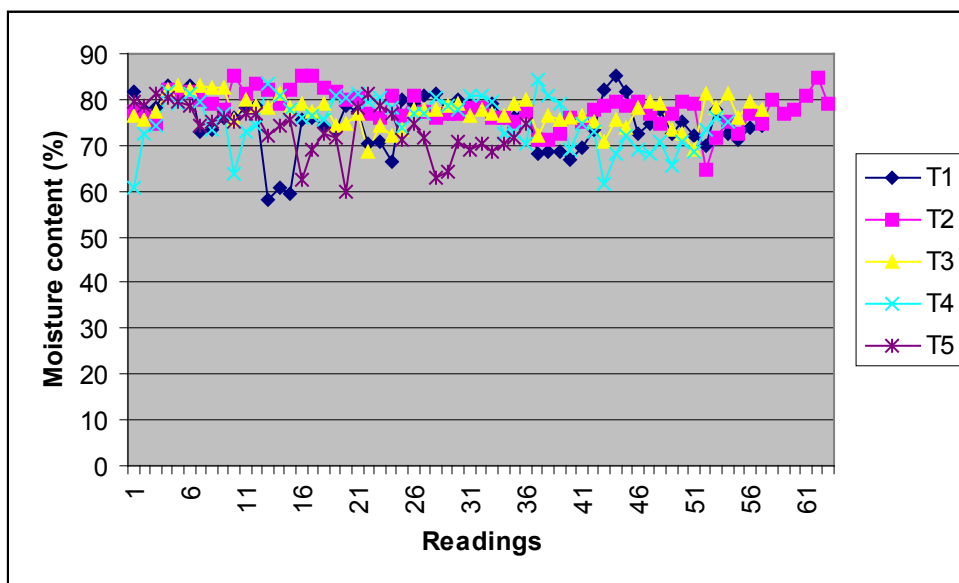


Figure 2: Plant Moisture Content (%)

In summary, results from this study showed significant differences between treatments for plant moisture content at 68 DAS. The water content of rice plant was in the order of T2>T3>T4>T1>T5. Moisture content also showed significant differences between replicates in the order of R1>R2>R3>R4, in rice plant.

Leaf Stomatal Conductance

Results showed the order of importance in leaf stomatal conductance at T2 > T1 = T4 > T3 > T5 (Table 3), even though the difference was not significant notably due to higher variability in readings; as shown from the early flooding for the first month followed by saturated or F-30 saturated (T3) treatment as well as in the continuous field capacity condition throughout the growth stage (T5) treatment (Fig. 3). These results were possibly influenced by changes in atmospheric temperature on leaf surfaces that affect the boundary layer (Salisbury and Ross, 1992) during the long hours of daily measurement. Nevertheless there was an indication of increased transpiration from leaf in the early flooding up to panicle initiation stage followed by saturated or F55-saturated (T2) treatment. *Oryza sativa* var. MR220 notably showed the ability for dehydration avoidance to water stress, demonstrated by leaf rolling, causing the reduced water loss.

Table 3. Leaf Stomatal Conductance (mmol m⁻² s⁻¹)

	Treatment				
	T1	T2	T3	T4	T5
AVERAGE	450	462	447	450	424
SD	93	86	147	82	105
% CV	21	19	33	18	25

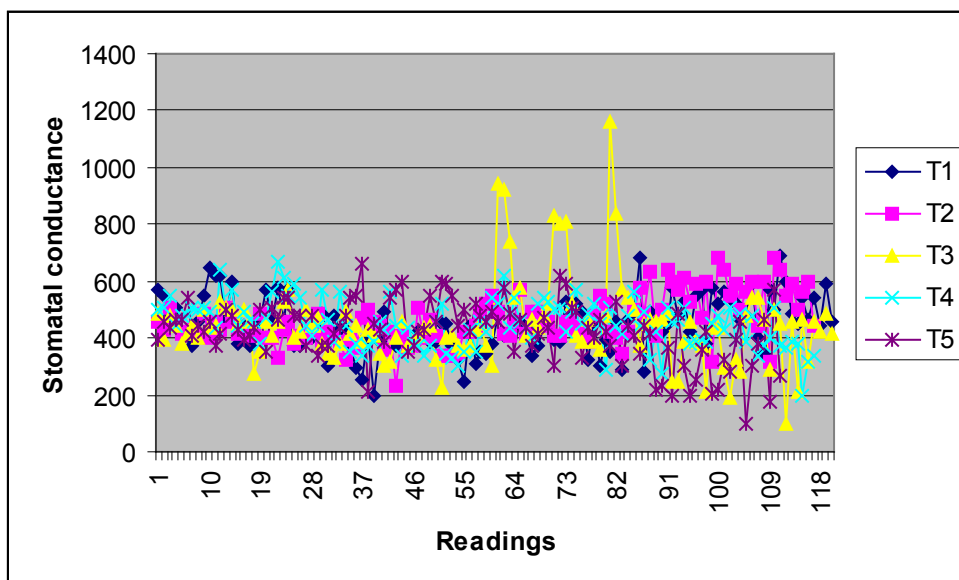


Figure 3: Leaf Stomatal Conductance (mmol m⁻² s⁻¹)

In summary, results from this study showed no significance different in leaf stomatal conductance at 68 DAS.

Soil plant transfer coefficient of mineral element

The soil plant transfer coefficient of nitrogen, potassium, magnesium and sodium was studied in rice *Oryza sativa* var. MR220 plants in all treatments (Tables 4, 5, 6 and 7).

Nitrogen mineral showed the highest transfer coefficient values that ranges between 8.11 to 5.75; in the order of T4 > T3 > T2 > T1 > T5 (Table 4). Nitrogen metabolism is a major factor in vegetative growth of plant in leaf and stem. It is a constituent of many important molecules that include proteins, nucleic acids, hormones, chlorophyll, vitamins and enzymes that are essential for plant life (Hopkins and Huner, 2004). A deficiency in nitrogen causes leaf yellowing and stunt growth that results in reduced yield, whereas excess nitrogen delays flowering and fruiting (Morgan, 2006).

Table 4. Soil Plant Transfer Coefficient of Nitrogen (N)

N	Treatment				
	T1	T2	T3	T4	T5
Content in plant (%)	1.87	2.00	1.87	2.19	1.84
Content in soil (%)	0.32	0.28	0.25	0.27	0.32
TF	5.84	7.14	7.48	8.11	5.75

Soil plant transfer coefficient of potassium was also high at values between 1.45 to 0.55. The order of importance in all treatments was T3 > T1 > T2 > T4 > T5 (Table 5). Potassium is important for water balance adjustment, stem rigidity and cold hardiness improvements, flavor and color enhancements in fruit and vegetable crops, as well as for increasing the oil content of fruits. It is also important for leafy crops, and deficiencies result in low yields, mottled, spotted or curled leaves, scorched or burned look to leaves. Potassium is necessary for formation of starch, carbohydrate, sugar, protein synthesis and cell division in roots and other plant parts (Morgan, 2006).

Table 5. Soil Plant Transfer Coefficient of Potassium (K)

K	Treatment				
	T1	T2	T3	T4	T5
Content in plant (%)	13.06	13.77	13.48	11.62	10.39
Content in soil (%)	9.27	11.69	9.29	10.94	19.03
TF	1.41	1.18	1.45	1.06	0.55

Soil plant transfer coefficient of magnesium in rice was low at between 0.34 to 0.00; in the order of T5 > T1 > T3 > T4 > T2 (Table 6). Magnesium is a critical structural component of the chlorophyll molecule and deficient plants appear chlorotic, show yellowing between veins of older leaves and leaf drooping. Since magnesium is easily leached by watering, it must be supplied by applying fertilizer in a foliar spray to correct these deficiencies. Magnesium is also necessary for functioning of plant enzymes to produce carbohydrate, sugar and fat. It is used for fruit and nut formation and essential for germination of seeds (Morgan, 2006).

Table 6. Soil Plant Transfer Coefficient of Magnesium (Mg)

Mg	Treatment				
	T1	T2	T3	T4	T5
Content in plant (%)	3.70	0.00	2.29	2.04	3.94
Content in soil (%)	12.15	11.82	10.04	10.58	11.67
TF	0.30	0.00	0.23	0.19	0.34

Soil plant transfer coefficient of sodium in rice was low at between 0.27 to 0.10; in the order of T1 > T2 > T3 > T4 > T5 (Table 6). Thus sodium transfer from soil to rice plant was following a similar trend as the soil moisture content (Table 1). Sodium is important in osmotic (water movement) and ionic balance in plant (Morgan, 2006).

Table 7. Soil Plant Transfer Coefficient of Sodium (Na)

Na	Treatment				
	T1	T2	T3	T4	T5
Content in plant (%)	0.25	0.20	0.18	0.17	0.14
Content in soil (%)	0.91	0.97	0.90	0.90	1.45
TF	0.27	0.21	0.20	0.19	0.10

In summary, the the highest order of importance recorded was in the continuous saturated (T4) treatment for nitrogen, the early flooding for the first month followed by saturated (T3) treatment for potassium, the continuous field capacity condition throughout the growth stage (T5) treatment for magnesium, and the continuous flooding (T1) treatment for sodium.

CONCLUSION

Soil moisture content and plant moisture content were significantly different between different water regimes, but there was no significance different recorded in the leaf stomatal conductance at 68 DAS. The order of importance in the moisture contents of rice plant as recorded from different water regimes was also not in tandem with that of the ricefield soil. However, the order of importance in the moisture contents of ricefield soil from different water regimes (T1 > T2 > T3 > T4 > T5) coincided with that of soil plant transfer coefficient of sodium nutrient element.

ACKNOWLEDGEMENTS

The authors wish to express utmost gratitudes to Mrs. Latiffah Norddin, Mrs. Maizatul Akmam Mohd. Nasir, Mrs. Jamaliah Mat Yatim, Mr. Ariffin Talib, Mrs. Hazlina Abdullah and Mrs. Salmah Moosa from Malaysian Nuclear Agency, and Mr. Mohd. Rosmadi Mohammad from the MARDI Kubang Keranji Research Station, Kota Bharu, Kelantan for their assistance in the field and laboratory. This project was funded by IRPA 01-01-03-0000PR0068/05-04.

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