SELECTION OF RICE (*ORYZA SATIVA L*) VARIETIES FOR LOWLANDS RAIN-FED CONDITIONS IN PAPUA NEW GUINEA.

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ABSTRACT

Four rice (Oryza sativa L.) varieties, NR 1, NR 9, NR 15 and NR 16 were provisionally released in 2003 by the National Agricultural Research Institute (NARI) for the lowland areas ranging from 0-1200 meters altitude. They were selected on the basis of grain yield, eating quality and pest and disease resistance from the first season of trials.. The varieties were tested by NARI for another two seasons at five different sites in the Madang and Morobe Province. The superior performance of the four NR varieties over the standard varieties TCS 10 and FB91 was confirmed in both seasons. The varieties NR 1, NR 9, NR 15 and NR 16 are recommended for final release to farmers in the Lowlands of PNG based on yield performance and taste.

Keywords: *Varieties, released, National Agricultural Reseach Institute, seasons, performance.*

INTRODUCTION

Rice (*Oryza sativa L*) has many advantages over most of the traditional food crops of Papua New Guinea (PNG). Rice is easy to store, does not perish during transportation to distant locations, consumption of small volumes is enough to satisfy the human appetite compared to the traditional root crops and is considered a novel food. Unfortunately the crop has not integrated well into the farming systems of PNG. Non-availability of suitable varieties (with superior agro botanical and physiochemical traits) and lack of agronomic information have been reported to be the two of the major constraints for rice production in PNG (Sajjad 1995; Sajjad 1998).

Numerous efforts to evaluate introduced varieties suitable for PNG conditions have been accomplished in the past, but only a few of these have been published (Wohuinangu and Kapp 1982). The most predominant work was done by the Department of Agriculture and Livestock at Bubia Agricultural Research Centre, where a limited number of varieties imported from IRRI by the end of 1960, were evaluated across seven sites ranging from Dumpu in the Ramu Valley to Munum in the lower Markham valley. The results of the studies were non conclusive due to lack of information for optimum planting dates for the sites, soil conditions, erratic rainfall, Rice bugs (*Leptocorisa* spp.) and unsuitable varieties (Sumbak 1977).

Superior and modern varieties with ideal agro-botanical and physico-chemical traits and agronomic information are pre-requisites to developing domestic rice production (Ten 1974). Several promising varieties were identified and recommended for cultivation in PNG by various researchers in the past (Sajjad 1995; Sajjad 1996a; Sajjad 1996b; Sumbak 1977; Wohuinangu & Kapp 1982). These varieties, however, were recommended for release prior to investigating the stability of their performance across varying environments.

A study was conducted to evaluate adaptability of promising rice varieties under different environments in PNG. Based on the results of the first season of trials, four rice varieties were provisionally released for upland cultivation in areas ranging from 0-1200 meters altitudes. The four varieties NR 1, NR 9, NR 15 and NR 16 were selected on the basis of grain yield, eating quality and pest and disease resistance (Wamala 2003 and Waramboi *et al* 2003). Results of the second season of trials were discussed in Okpul *et al.* 2005. This paper reports on the third seasons of multi-location trials and compares performance of promising varieties across all three seasons of multi-location trials.

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MATERIALS AND METHOD

Location and Methods

A series of multi-location trials was conducted between 2001 and 2005 at different sites in Madang and Morobe Provinces to evaluate the performance of upland rice varieties across different envioroments. Trial 1 was conducted at Intoap (Mutzing), Gusap (Ramu Sugar), Usino, Wareo (Finchafen), and Garaina while Trials 2 and 3 were conducted at Intoap, Gusap, Usino, Boana and Dagging. Table 1 shows the soil and agro-ecological features of all the sites used during the series of trials.

Soils at the trial sites were moderately fertile with acid to moderately acid soil pH, low organic matter and total nitrogen and phosphorous low but medium to high ratings for Mg and K at most sites. Data for Wareo are not available (Appendix Table A1).

The rice varieties were among 1250 accessions introduced from the International Rice Research Institute (IRRI) since 1960 (Sumbak 1977). From previous trials conducted between 1991 and 1996 initial eight upland rice varieties were selected for the season of multi-location trials. The number of varieties was increased to 10 varieties for seasons 2 and 3 (Table2).

***Table 1*. Experimental sites and their agro-ecological features**

Sites	Province	Average annual Rainfall (mm)	Seasonality of rainfall (mm)	Average Temperature (°C)	Average Humidity (%)	Soil texture	Altitude (m.a.s.l)
Intoap [1,2]*	Morobe	1500-2300	100 - 350	34	84	Sandy loam	200
Gusap[1,2]*	Madang	1500-2300	100 - 200	32	83	Clay loam	300
Saussi[1,2]*	Madang	3500-4000	200 - 350	33	92	Loamy	300
Boana[2]	Morobe	2000-2500	100 - 200	27	90	Silty clay loam	940
Dagging[2]	Morobe	4000-5000	200-350	29	94	Clay loam	600
Garina[1]	Morobe	1500-2700	100-250	30	85	Clay loam	<600
Wareo[1]	Morobe	2400-3700	200-300	29	94	Clay loam	>600

[1]Trial sites in season 1 (2001/2002).
[2]Trial sites in season 2 and 3 (2003/2004, 2004/2005)
*= Sites common for all three seasons

***Table 2*. Rice varieties evaluated at five different sites in Papua New Guinea**

NARI codes[a]	Source	Donor name/ No.	Origin	Plant height
NR 1 [1,2]*	IRRI[4]	IR 19961-23-2-2	Philippines	Short
NR 2[1]	IRRI	Ayung	Indonesia	Short
NR 4 [1,2]*	IRRI	BG 379-2	Sri Lanka	Short
NR 9 [1,2]*	NARI[5]	N6-94	PNG	Medium
NR 11[2]	IRRI	IR 841-1-1-2	Philippines	Medium
NR 13[2]	IRRI	IRAT 104	Ivory Coast	Short
NR 14[2]	IRRI	IRAT 170	Ivory Coast	Short
NR 15 [1,2]*	IRRI	Salumpikit	Philippines	Tall
NR 16 [1,2]*	IRRI	Azucena	Philippines	Tall
FB 91 [1,2]*	Unknown	Finsch Brown 91 (standard)	Finschhafen	Tall
TCS10 [1,2]*	TATM[6]	Taichung Sen 10 (standard)	Taiwan	Medium

[1]Varieties evaluated in trial 1
[2]Varieties evaluated in Trial 2 and 3
*Varieties evaluated in all 3 trials
[4]International Rice Research Institute; [5]National Agricultural Research Institute;
[6]Taiwanese Agricultural and Technical Mission

Trial design and maintenance

The trial at each site was planted using a randomized complete block design and replicated five times. Planting was done in December and harvested the following year following the normal rainy season (figure 1). About five seeds were sown per hole at a plant spacing of 20 x 20 cm between rows and plants. The plot size was 15 m ^{2}. At each site inorganic fertilizer was applied at the rate of 100: 50: 50 Kg-ha $^{-1}$ N, P and K. All P, K and 40 % of N were applied at the time of planting. The two top dressings were applied with N (30 % each) in the form of urea (46 % N) at 25 and 45 days after the planting date. Hand weeding was done twice prior to fertilizer application. The series of trials was harvested at four months after planting. TC Seng 10 (TCS 10) and Finch Brown (FB 91) were used as control varieties.

Data collection and Statistical Analysis

Data were collected from 25 randomly selected hills from each plot representing 1m^{2} after removing the guard rows. Various plant growth parameters were measured including yield, plant height, panicle length, % spikelet fertility and Thousand Kernel Weight (TKW). Grain yield per plot was measured at 14 % seed moisture content in g and converted to t/ha. Incidence of pest and diseases on different varieties was recorded at each site and assessed using the Standard Evaluation System provided by IRRI (IRRI, 2002a).

First, the results of the multi-location trials of the third season were considered. Data of all sites were then pooled and ANOVA was used to quantify sources of variation in the data set. The second part of the analysis considered a data set of common sites and varieties across all three seasons. ANOVA was applied to compare mean yield data of seven varieties at three sites across three seasons.

ANOVA was performed using software Genstat® version 3.2 for each site and means were separated using Least Significant Difference (LSD) and pooled for the combined results across the five sites.

RESULTS

Third season (2004-2005).

The results for mean grain yield (t/ha) of the ten rice varieties tested in five locations in the third season of multi-location trials are presented in Table 3. A summary of results for the other parameters measured is presented in Table A2 in the Appendix. There were significant differences ($P<0.01$) between varieties as well as between sites. There was also a significant Site x Variety interaction (Table 4). The mean yield over the ten varieties ranged from 3.62 t/ha (FB 91) to 6.31 t/ha (NR 9) (Table 3). Average yield of the ten varieties was 5.48 t/ha. All NARI varieties performed significantly better compared to TCS 10 and FB 91. There were significant differences between NR varieties in the mean yield data across all sites (Table 3).

Table 3. **Mean grain yield (t/ha) of ten rice varieties tested in five locations in Papua New Guinea for the third season (2004-2005)**

Variety	Boana	Dagging[1]	Intoap	Gusap	Sausi	Mean
NR 9	7.07^{c2}	7.58^{cd}	8.84^{c}	3.26^{c}	4.81^{ab}	**6.31^{e}**
NR 14	7.17^{c}	7.64^{cd}	7.85^{c}	1.89^{a}	6.10^{b}	**6.14^{de}**
NR 16	7.44^{c}	6.48^{bc}	7.32^{bc}	3.06^{c}	6.31^{b}	**6.12^{cde}**
NR 4	7.19^{c}	6.75^{bcd}	N/A	3.12^{c}	5.71^{b}	**5.93^{cd}**
NR 15	4.17^{ab}	8.25^{d}	7.66^{c}	3.5^{c}	5.37^{b}	**5.79^{cd}**
NR 1	6.90^{c}	6.55^{bcd}	7.2^{bc}	3.45^{c}	5.59^{b}	**5.94^{cd}**
NR 13	7.07^{c}	6.48^{bc}	4.95^{ab}	3.08^{c}	5.41^{b}	**5.40^{c}**
NR 11	5.99^{bc}	6.91^{bcd}	4.93^{a}	2.81^{bc}	4.99^{b}	**5.13^{c}**
TCS 10	6.71^{c}	5.50^{b}	N/A	3.14^{c}	3.30^{a}	**4.92^{b}**
FB 91	3.72^{a}	3.52^{a}	3.21^{a}	2.09^{ab}	5.56^{b}	**3.62^{a}**
Mean	**6.32**	**6.57**	**6.50**	**2.94**	**5.32**	**5.49**
% CV	**23.9**	**20.7**	**23.7**	**22.3**	**24.8**	

[1]The local standard variety at Dagging was Finch Brown while at other sites TCS 10 was used.
[2]Numbers followed by the same letter are not significantly different at $p<0.05$ using Least Significant Differences

Table 4. **Pooled analysis of variance of grain yield (t/ha) of the ten rice varieties tested at the five sites in Papua New Guinea.**

Source of Variation	Degrees of Freedom	MS
Variety (V)	9	15.85**
Site (S)	4	114.19**
S x V	34	5.50**
Residual	172	1.97

** = Significant at the 1% probability level.

Among sites, all varieties at Gusap performed significantly lower than other sites. In individual sites ranking of varieties according to yields was different causing the significant (SxV) interaction, but among the NARI varieties only NR 15 was significantly different to other NARI varieties in Boana and Dagging (lowest and highest) and NR 14 at Gusap. In almost all sites FB 91 (local landrace) had the lowest yield except at Sausi where TC Seng 10 had the lowest yield. At Intoap the variety NR 04 could not be harvested due to heavy lodging and spikelets of TCS 10 had 100% sterility as a result of drought conditions during the reproductive phase. This variety had to be replanted twice as a result of poor germination rates.

Incidences of pests and diseases at trial sites were variable across sites (data not shown). Intoap was free of pests and diseases while Usino showed the highest incidence of pests. Most varieties were affected by the rice bug (*Leptocorisa oratorius*) with more severe infestation on NR 01, 11 and 09, stem borer (*Chilo sp.*) and leaffolder (*Cnaphalocrocis medianalis*). Dagging had the highest incidence of diseases among sites where brown spot (*Bipolaris oryzae*) and sheath blight (*Rhizoctonia solani*) were observed on a number of varieties, in particular NR 01, 04 and 09. Brown plant hopper *(Nilaparvata lugens)* and false smut (*Ustilaginoidea virens*) occurred in low incidence on a few varieties at different sites.

Comparison of results across three seasons

In order to establish how the rice varieties performed across different seasons the yield results of all common sites and varieties across the three seasons were pooled and subjected to statistical analysis. Comparisons across seasons showed that all five NARI varieties performed significantly better compared to the control varieties TCS 10 and FB 91. NR 15 performed consistently well across seasons. The yields for 2003/2004 seasons were the lowest for most varieties (Table 5).

Table 6 shows the mean data across three seasons for other plant growth parameters measured during the series of multi-location trials. Most parameter show significant differences between varieties except for Spikelet fertility (SF). SF ranged between 72.5% in TCS 10 to 83.5% in NR16. NR01 and NR 04 are the shortest varieties while FB 91 grows tall with 151.9 cm. There was little variation among varieties for the Number of Productive Tillers and Panicle Length. FB 91 produced significantly less number of tillers but had the longest panicle among varieties. It also produced the highest Thousand Kernel weight

Table 5. **Mean yield (t/ha) of seven rice varieties evaluated at three sites across three seasons in the Lowlands of Morobe and Madang Provinces from 2001-2005.**

Variety	Mean yield (t/ha) 2001-2002*	Mean yield (t/ha) 2003-2004*	Mean yield (t/ha) 2004-2005*	Mean*	Ranking
NR 15	6.29^{e}	4.27^{ab}	5.52^{c}	5.36^{d}	*1*
NR 1	5.53^{d}	4.45^{b}	5.43^{c}	5.14^{cd}	*2*
NR 9	5.29^{cd}	3.92^{ab}	5.63^{c}	4.95^{c}	*3*
NR 16	5.05^{bcd}	4.13^{ab}	5.56^{c}	4.91^{c}	*4*
NR 4	4.74^{bc}	4.67^{b}	5.25^{c}	4.89^{c}	*5*
TCS-10	4.50^{ab}	3.73^{ab}	4.2^{b}	4.14^{b}	*6*
FB 91	3.97^{a}	3.03^{a}	3.62^{a}	3.54^{a}	*7*
Mean	**5.05**	**4.03**	**5.03**	**4.70**	

*Numbers followed by the same letters are not significantly different at p<0.05 using Least Significant Differences.

followed by NR 15 and NR 16. The number of Days to Maturity was only available from the 2001/2002 seasons. NR 15 reached maturity already after on average 104 days while FB 91 had the longest growth period of 145 days.

DISCUSSION

The last series of multi location trials and the comparisons of yield performance of rice varieties have confirmed that the varieties released provisionally by NARI in 2003 are superior in regards to yield performance compared to the widely distributed variety TCS10 and the local landrace FB 91. Additionally variety NR 4 has emerged as another variety that can be considered for release to farmers.

Consistent with trials in previous seasons (Wamala, 2003; Okpul *et al.* 2005) all NARI varieties produced significantly higher yields compared to the control varieties TCS 10 and FB 91 in 2004/2005. This is confirmed by the mean yield results of the varieties tested in all three seasons (Table 5). Discrepancies in yield potentials of varieties at different locations and in different seasons may be due to genotype x environment interaction caused for example by different times of planting, rainfall or soil types (Sajjad 1995).

The variety FB 91 was the lowest yielding variety throughout the three seasons. The origin of this variety is not known but it is considered a landrace as it has been commonly grown in Finschhafen for a long time. There are three major types of rice recognized worldwide. They are the Indica, Javanica and Japonica types, each differing in morpho-ecological characteristics. FB 91 shows typical characteristics of a Javanica type rice with low tillering rate, long panicles, tall plant stature and high Thousand Kernel Weights (Table 6) (IRRI 2002b). Sumbak (1977) reported that Javanica type varieties were tall and susceptible to lodging which results in lower yields. Sajjad (1995) also reported a similar trend when comparing FB 91 against Niupela and IAC 165, two Indica types, where the yield of FB 91 was lower.

Among the trial sites, the site at Gusap produced the lowest yields in the 2003/2004 and 2004/2005 season, while the yields at other sites were not much different to each other (Okpul *et al.* 2005, Table 3). Soil characteristics at Gusap are fairly similar to other sites (Table 1) with medium soil pH, medium to high content of extractable bases, cation exchange capacity, low organic matter and available P and N. Low organic matter was also reported in a study by Harteminck (2000) on land management in Ramu Sugar Plantations. Low rainfall at grain filling stage may have affected the yield in the 2003/2004 season at Gusap as reported by (Nass-Komolong 2005) (Figure 1). More rainfall was experienced in the 2004/2005 seasons during the reproductive phase at Gusap (Figure 1). However, as there are no weather data available for other sites it is not possible to draw further conclusions regarding the influence of rainfall on yield performance. Basic weather data should be recorded at all trial sites in future trials.

Pests and diseases are other important factors that may influence yield performance of rice varieties. This has not been studied in detail for the varieties in question. During the trials incidence of pests

Table 6. **Mean data for six-plant growth parameters of seven rice varieties evaluated in three locations in Morobe and Madang Provinces from 2001-2005**

Variety	PH[1] (cm)	No. of PT[2]	PL (cm)[3]	SF (%)[4]	TKW[5] (g)	D to M[6,7]
FB 91	152[d,8]	8.7[a]	29.9[c]	80.6[9]	34.3[c]	145
NR 01	83[a]	18.3[d]	22.5[ab]	77.3	25.0[a]	132
NR 04	82[a]	15.4[cd]	22.1[ab]	76.2	23.1[a]	134
NR 09	105[bc]	11.8[ab]	21.8[a]	74.4	23.5[a]	135
NR 15	113[c]	14.2[bc]	22.2[ab]	75.0	29.6[b]	104
NR 16	111[c]	12.9[bc]	22.6[ab]	83.5	28.0[b]	113
TCS 10	94[ab]	14.2[bc]	23.9[b]	72.5	25.1[a]	133

[1]PH – Plant Height; [2]PT – Number of Productive Tillers; [3]PL – Panicle Length; [4]SF – Spikelet Fertility; [5]TKW – Thousand Kernel Weight; [6]D to M – Days to Maturity

[7]Days to Maturity data are only available from the first season in 2001/2002

[8]Numbers followed by the same letter are not significantly different at $p<0.05$ using Least Significant Differences

[9]not significant at $p<0.05$

and diseases was recorded but infestation levels varied from site to site and from season to season. Infestation with the Rice bug (*Leptocorisa oratorius*) affected a number of varieties such as NR 01, NR 09 and NR 11, which may explain their relatively lower yield at Gusap compared to other sites in the 2004/2005 seasons.

Stability performance established by Okpul *et al* 2005 found that NR 11, NR 13 and NR 14 were responsive to favorable environments. This was confirmed in 2004/2005 when NR 14 was among the highest in fertile sites (Boana) but lower in poor site (Ramu). These varieties could be used by semi commercial farmers who can afford to produce rice using higher inputs such as the use of fertilizer.

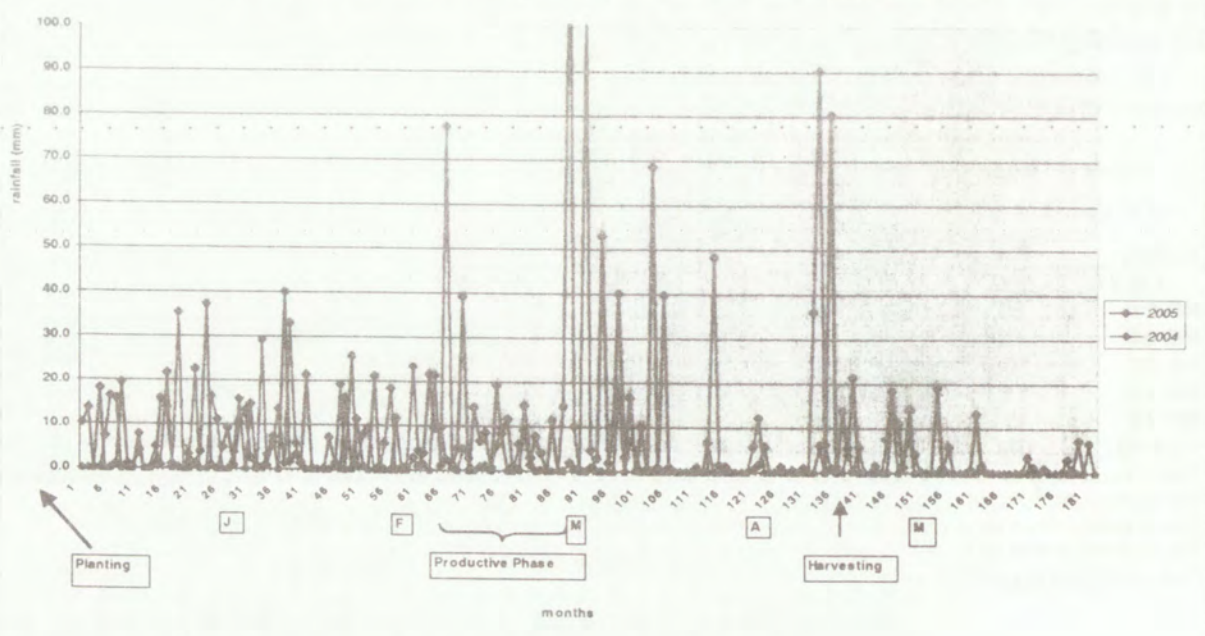
Comparison of rice varieties across three seasons showed the superior performance of NR varieties compared to control varieties FB 91 and TCS 10 in regards to yield. In the 1990s the Department of Agriculture and Livestock (DAL) screened about 1,149 exotic genotypes introduced from IRRI as part of a Rice and Grain Research and Development Project among them the varieties NR 13 (IRAT 104), NR 14 (IRAT 13), NR 15 (Salumpikit) and NR 16 (Azucena) (Sajjad 1994a, Sajjad 1994b, Sajjad 1995). Varieties tested in those trials showed generally lower yields. However, Sajjad (1995) reported that the trials were grown under minimum input conditions with no or only one basal fertilizer application and reduced weeding. The varieties NR 15 and NR 16 were either considered for release or for advanced elite selection (Sajjad 1994a; Sajjad 1994b).

Eating quality, milling and physico-chemical characteristics are important factors to be considered before variety release. Sumbak (1977) stated that a lot of varieties tested in the past with high yields were superseded or discarded because of inferior cooking qualities. Waramboi *et al*. (2003) studied the eating quality of the rice varieties used in the first season of multi-location trials. Results showed that among NR varieties, NR 01, NR 16 and NR 09 were preferred over NR 15 and NR 4.

Resistance to major pests and diseases of varieties evaluated in this series of multi-location trials is another important consideration for variety release. However, little is known about levels of resistance among these rice varieties. Previous data are not available and during the multi-location trials varieties were not sufficiently exposed to various pest and diseases for any conclusions on varietal resistance. A small study on resistance of NR 01, 04, 09, 15, 16 and TCS 10 against the Brown Plant Hopper is in the planning stage at the NARI Wet Lowlands Mainland Programme.

In conclusion, the four varieties that were released on a provisional basis in 2003 have consistently produced higher yields compared to the control varieties TCS 10 and FB 91 across different environments. The varieties show a good mixture

Figure 1 Rainfall (mm) in Ramu Sugar during the month of January to May 2004 and 2005



of different maturity times with two early maturing varieties (NR 15 and 16) and varieties with variable plant heights. NR 01 and 09 are short varieties that may give advantages in areas with higher risks of lodging. Consumer preference studies (Waramboi *et al*. 2003) showed that the varieties are well liked by consumers. Based on this information they should be formally released. NR 04 is a short variety similar to NR 01 and 09 in its maturity time and other features. It also produces superior yields but is not as well liked by consumers. This variety may be considered for release if it shows to be superior in other traits such as resistance to pest and diseases. This work is still in progress at the National Agricultural Research Institute.

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APPENDIX

The Dagging and Gusap sites were tested in (2002-2003) season while the Boana, Intoap and Sausi site sample were tested for the (2004-2005) season.

Table 1. Soil Analysis Results

Location	pH	Extractable Bases				CEC	Olsen P	Organic	Total	Particle size %		
		Ca	Mg (me %)	K	Na	(me%)	(mg/kg)	C (%)	N (%)	sand	silt	clay
Boana	4.3*	13.9	0.9	0.05	0.09	29.7	4.3	7.6	0.4	29	27	44
Dagging	5.8	16.5	7.21	0.21	0.15	34.8	5.9	2.73	0.29	7	39	54
Intoap	6.3	17.9	9.88	0.73	0.35	18.7	25.4	1.52	0.14	36	39	25
Gusap	6.0	15.5	5.24	0.87	0.14	23	20	2.54	0.2	21	30	49
Sausi	5.4	12	9.7	0.14	0.05	44.2	1.6	2.38	0.2	31	29	40
Critical values	<5.5	<5.0	<1.0	<0.3	>0.7	<6.0	<5.0	<3.0	<0.3			

* Values lower than the others.
Soil samples were analyzed by National Agricultural Chemistry Laboratory (KilaKila) Using methods NACL-Standard Methods

Table 2. **Means of various growth parameters of ten varieties across five sites in 2004/2005 season**

Variety	PH[1] (cm)	No. of PT[2]	SF (%)[3]	FLA (cm^2)[4]	TKW[5]
NR 1	86.5	21.06	69.47	33.3	N/a[6]
NR 4	84.1	17.08	74.15	32.5	N/a
NR 9	121.8	13.44	76.94	69.2	N/a
NR 11	76.2	16.14	78.69	39.6	N/a
NR 13	129.0	9.00	77.67	83.1	N/a
NR 14	65.56	18.06	72.51	36.6	N/a
NR 15	122.3	16.52	75.76	51.5	N/a
NR 16	117.3	12.82	85.10	55.7	N/a
TCS 10	98.6	15.10	65.88	45.4	N/a
FB 91	167.9	8.74	83.79	83.1	N/a

[1] PH – Plant Height; [2]PT – Number of Productive Tillers; [3]SF – Spikelet Fertility;
[4] FLA – Flag leaf area; [5]TKW – Thousand Kernel Weight; [6]not available – data not collected in 2004/2005 season