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Population Management for Yield Improvement in Upland Rice Ecologies for West Africa Region

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1. Introduction

Rice has become a commodity of great importance in West and Central Africa (WCA), due to rural-urban migration, population growth and rapid urbanisation. These factors could be responsible for sudden change in the dietary preferences of consumers. Rice consumption rate was estimated to be growing by 5.6 % per annum, more than double the rate of population growth in WCA (WARDA, 1997). Currently, rice ranks fourth as most important grain crop in Africa, behind maize, sorghum and millet and West Africa region dominates the continent production (DeVries and Toenniesen, 2001).

In West Africa, the rainfed upland is important rice ecology; it represents 57% of total rice area and 40% of regional production with a potential yield of 2.5 to 4.5 tonnes/ha. However, in the farmers' field, yield realised is often very poor, not more than 1 tonne/ ha (Efisue et. al. 2008).

Apart from biotic and abiotic stresses attributed to farmers' low yield; there are inherent low-yield and poor agronomic characters in most of the rice cultivars currently in the farmers' fields. Although, high yielding Asian rice (*O. sativa)* is widely cultivated, it is very susceptible to biotic and abitioc stresses. The indigenous African rice (*O. glaberrima)*, unfortunately, has many undesirable agronomic characters such as grain shattering, long dormancy, and weak culms that lodge easily, which resultin low yield grain potential (Jones et al. 1997).

Farmers in West Africa still grow mixed proportion of these rice species (*O. glaberrima*, 15% and *O.sativa*, 20%) of the total rice area (WARDA, 1993), while in some areas like Gao region of Mali a larger area is grown to *O. glaberrima* rice. The continuous growing of *O. glaberrima* might be due to some of its good agronomic characters, such as taste, aroma, and excellent vegetative growth which suppresses weeds (Dingkuhn et al., 1998). Jones et al. (1997) reported that *O. glaberrima* represents an invaluable reservoir of useful genes for biotic and abiotic stresses such as drought tolerance genes.

Thus, resource-poor farmers would appreciate developing an ideal variety that could perform well in any condition with higher yield potential. The major concern for rice breeders is to develop varieties with high yield potential, which is the result of several components that are determined at various stages in the growth of rice (Yoshida, 1981). Effective population management will enhance yield potential by selecting promising genotypes from the early generations of the rice crop, thus reduce the carry-over of undesirable materials into the next generation of the breeding cycle. The objectives of the study are to identify high yielding lines and desirable agronomic characters through population management practices for upland rice ecologies.

2. Materials and methods

2.1 Experimental site and weather conditions in Mali

The rice populations were established at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) research station, Samanko, Mali in 2005 dry season. The soils were acidic and deficient in organic matter and total nitrogen. The soil texture was silty clay loam with very low cation exchange capacity. The soil was of low fertility. This resulted from inadequate levels of essential nutrients, especially Nitrogen (N) content of 0.058 %. The soil organic matter was low (0.480 %). Mali is located in sub-Sahelian vegetation belt in West Africa. It is a landlocked country located in the interior of West Africa between 12° W and 4° E longitude and 10 and 25° N latitude. The annual rainfall regime is monomodal, with distinct wet and dry seasons and air temperature very high during the early months of the year. The rainfall starts mainly in April and increases sharply in August, which is the peak period followed by sharp drop till October. The July and August receive about 60% of the annual rainfall, which shows the uneven distribution of rain in this region. The period between November and March (5 months) is virtually dry and no rain. This period also experiences the harmatan haze that blows from the Sahara desert to the Sahel region of West Africa. The mean monthly rainfall in the period under review was 86.12 mm. Mali has bimodal pattern in monthly air temperature and the air temperature increases from 34.8^0 C in January to 43.5^0 C in April, which is the hottest month. The second modal air temperature starts from August and increases gradually to November, and decreases thereafter till January.

2.2 Reference populations used for the experiment

The experiment comprised a total of 30 entries. They include 13 WBK populations derived from North Carolina design II mating scheme and were advanced to the F2 and F3 generations for seed increase by single plant selection. Eight lines (5 F6 and 3 F7) were selected at ICRISAT research station at Samako, Mali based on good agronomic characters from SIK 360 population received from Institut d' Economie Rurale (IER) at Sikasso Mali and 9 parental lines of these crosses (Table 1). The acrimony "WBK" is WARDA BAMAKO, while "SIK" is Sikasso.

3. Crop management and experimental design

The land was ploughed and disc harrowed and levelled before sowing the seeds. Dried seeds of rice were dibbled on shallow hole of 5 mm depth at the rate of three seeds per hole with a spacing of 20 cm within plants and 25 cm between rows and thinned to one plant per hole after 15 days of seedling emergency. The plot size was 1 m x 2 m (2 m^2) and a total of 44

Population	Pedigree	Generation
WBK 35	WAB 450-IBP-6-1-1/ WAB 365-B-1-H1-HB	F2
WBK 39	WAB 880-1-38-13-1-P1-HB / WAB 365-B-1-H1-HB	F2
WBK 40	WAB 880-1-38-13-1-P1-HB / WAB 375-B-9-H3-2	F2
WBK 41	WAB 880-1-38-13-1-P1-HB / NERICA 2	F2
WBK 39	WAB 880-1-38-13-1-P1-HB / WAB 365-B-1-H1-HB	F3
WBK 40	WAB 880-1-38-13-1-P1-HB / WAB 375-B-9-H3-2	F3
WBK 41	WAB 880-1-38-13-1-P1-HB / NERICA 2	F3
WBK 42	WAB 880-1-38-13-1-P1-HB / NERICA 3	F3
WBK 28	WAB 450-IBP-103-HB / WAB 375-B-9-H3-2	F3
WBK 35	WAB 450-IBP-6-1-1/ WAB 365-B-1-H1-HB	F3
WBK 150	WAB 880-1-38-13-1-P1-HB / NERICA 3// NERICA 2	BC1F2
WBK 106	WAB 450-IBP-6-1-1/ NERICA 3// WAB 375-B-9-H3-2	BC1F2
WBK 64	WAB 450-IBP-103-HB / WAB 375-B-9-H3-2// WAB 365-B-1-H1-HB	BC1F2
SIK 360-2-1-3-15-B	TOG 5681/ BG 90-2	F6
SIK 360-1-9-1-3-B	TOG 5681/ BG 90-2	F6
SIK 360-1-B-3-1-11-B	TOG 5681/ BG 90-2	F7
SIK 360-1-B-2-1-2-B	TOG 5681/ BG 90-2	F7
SIK 360-2-1-4-13-B	TOG 5681/ BG 90-2	F6
SIK 360-1-13-1-2-B	TOG 5681/ BG 90-2	F6
SIK 360-1-11-1-1-B	TOG 5681/ BG 90-2	F6
SIK 360-1-B-1-1-4-B	TOG 5681/ BG 90-2	F7
WAB 880-1-38-13-1-P1-HB	Parental line	P
WAB 450-IBP-103-HB	Parental line	P
WAB 450-IBP-6-1-1	Parental line	P
WAB 365-B-1-H1-HB	Parental line	P
WAB 375-B-9-H3-2	Parental line	P
NERICA 2	Parental line	P
NERICA 3	Parental line	P
TOG 5681	Parental line	P
BG 90-2	Parental line	P

Table 1. Rice populations, pedigree and generation of selection

plants stand per plot. Experimental design was an incomplete block of 5 x 6 rectangular lattice in two replications. Basal fertilizer was applied at the rate of 200 kg ha^{-1} of 17-17-17, N-P-K and top-dressed in two splits at maximum tillering and flowering stage with urea (46 % N) at the rate of 100 kg ha^{-1}. Hand weeding was done prior to each fertilizer application and there was no preventive treatment especially against diseases and insect pests.

4. Measurements

Measurements were taken as at when due for all traits using Standard Evaluation System (SES) for the Rice Reference Manual (IRRI, 1996). Before the commencement of data taken, 10 plants were labelled at random from the middle rows of each plot and these plants were used for all data taken.

4.1 Tiller number and plant vigour

Tiller number was taken at maximum tillering stage of the plant and a total of ten samples of plants per plot were randomly taken for measurement, and plant vigour was taken at 45 days after germination.

4.2 Effective tiller number and plant height

Effective tiller was regarded as the tiller that bear panicle for harvest and counts were taken from the 10 labelled plants and tiller number per plant was taken at maximum tillering stage, which correspond to panicle initiation (PI) stage. Plant height was measured from soil surface to the tip of the tallest panicle on the 10 labelled plants.

4.3 Days to flowering

This was regarded as anthesis time when about 50% of the plants in each plot have flowered and panicles were fully exserted.

4.4 Grain yield

Rice plants were harvested when less than 5% of the grain husk turned tan colour, the 10 labelled plants were harvested individually and only full grains were considered for yield. The entire plants in the two middle rows were harvested and bulked for yield determination. The grains were air-dried and final yields were adjusted to 14 % moisture content and 1000-grain weight was calculated from the seed lots for each sample.

4.5 Plant biomass and harvest index

All the plants harvested from the two middle rows and the 10 individual plants were air dried (average daily air temperature 37 ^{0}C) for three weeks for total dry matter determination and harvest index was (HI) calculated as grain yield per total dry matter, while panicle harvest index (PHI) was calculated as grain weight per panicle weight and grain to straw ratio was derived.

4.6 Panicle measurements

The following measurements were taken (1) number of full and empty grains per panicle was taken by removing the entire panicle grains and separated into full and empty grains, (2) the weight of the full and empty grains was taken. (3) Percentage sterility is referred to as the ratio of the empty grains to the total grains. (4) Panicle harvest index (PHI) was calculated as weight of full grain per panicle weight.

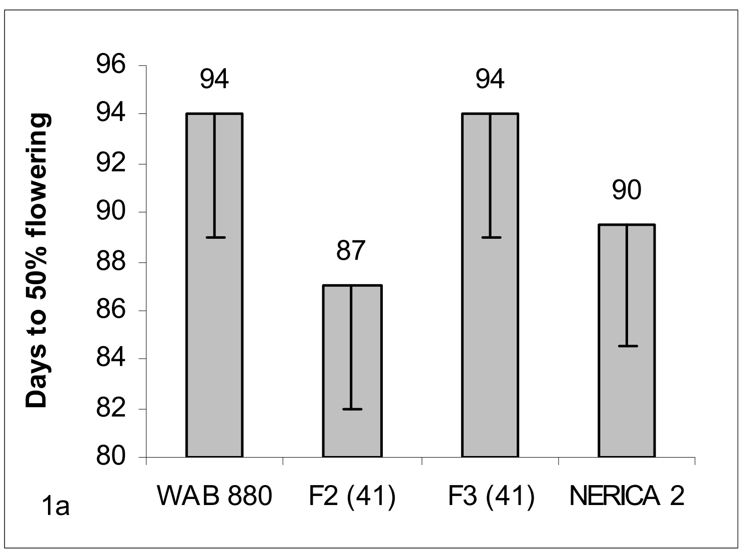
4.7 Statistical analysis

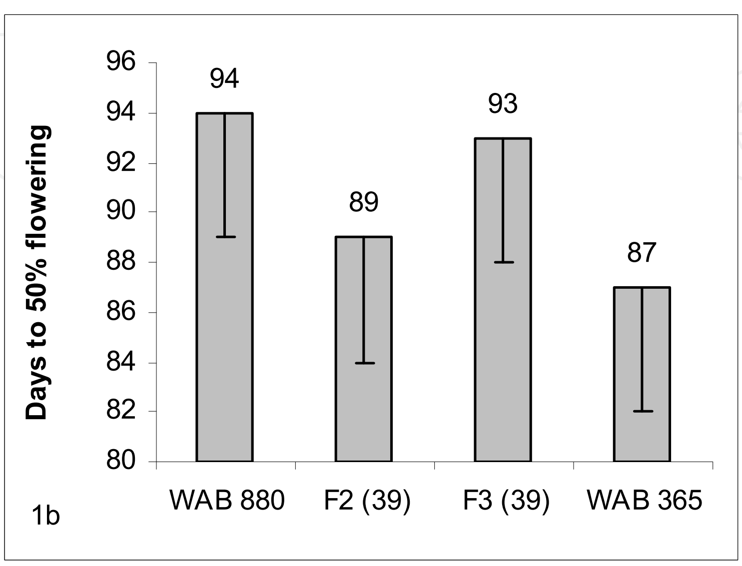
Analysis of variance (ANOVA) based on rectangular lattice design was performed for all measured traits using Statistical Analysis System (SAS, version 9.1, 2003) to test the significance of differences among genotypes.

5. Results

5.1 Effects of phenology on rice population management

Figure 1a is a cross between two interspecific lines, while Figure 1b and Figure 1c are crosses between interspecific and *O. sativa* lines (Table 1). Earliness is an important phenology in upland rice ecology, and selection for earliness among the rice populations could be important in rice production. It was observed that in the early generation of these crosses, larger proportion of the F_2 population skewed towards the early maturing parent (NERICA 2 and WAB 365 and WAB 6-1-1) while in later generation F_3, it skewed towards the late maturing parent (WAB 880). Due to the complex nature of these crosses there could be doubt of transgresive segregation in flowering. The F_1 progenies between *O.glaberrima* x *O. sativa* behave like *O. glaberrima* in most of the characters including flowering. This flowering behaviour between F_2 and F_3 in these crosses needs further investigation.





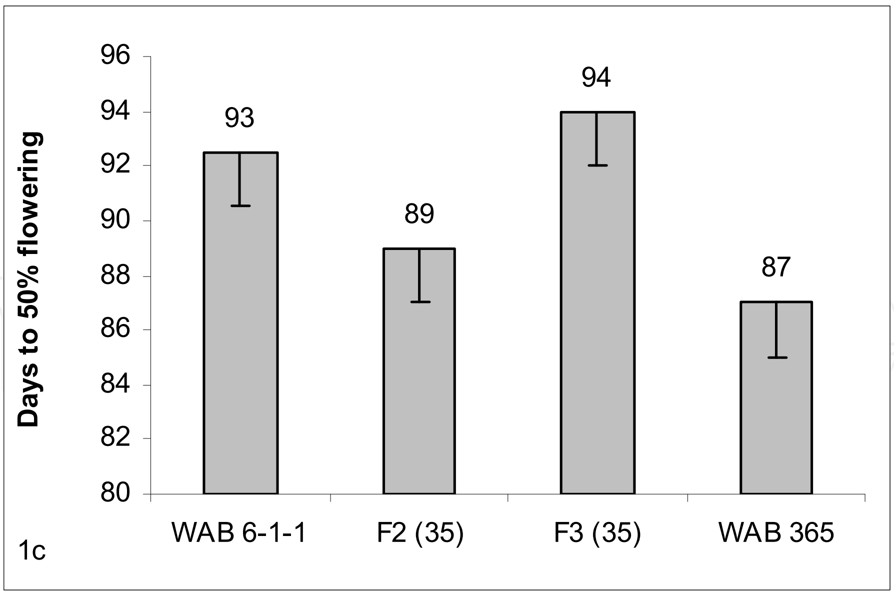


Fig. 1. Days to flowering of segregating populations (see Table 1 for populations code) .

6. Performance of populations and lines for some rice characteristics

The performance of rice populations and lines for some rice characteristics are presented in Table 2. Highly significant differences were observed among the rice populations for all the characters measured except the number of days to flowering ($P \leq 0.05$). Lines from SIK 360 population are photoperiod sensitive and their actual flowering dates could not be determined except for SIK 360-1-B-1-1-4-B and SIK 360-1-B-2-1-2-B now photoperiod-insensitive due to selections. The early maturing populations identified in this experiment are derived from either one of the early maturing parents such as WAB 365-B-1-H1-HB or NERICA 2 (Table 2).

The mean shoot dry weight of the F6 lines from SIK 360 populations was 626.88 g and F7 was 321.3 g, with a percentage decrease of 48.75% from one generation of the breeding cycle. Loss in shoot biomass was observed between F_2 and F_3 populations in all the crosses. This therefore raised concern on population management for rice production based on shoot biomass. The parental lines, TOG 5681 and BG 90-2 were higher in shoot dry weight as compared to the other parents including their progenies (Table 2).

Progenies from SIK 360 population were generally taller, with higher tillering ability and more vigorous than all the entries. These characters skewed towards the *O. glaberrima* parent (TOG 5681) except tiller number that skewed towards BG 90-2. Thus, this could indicate transgressive segregation for these characters and this phenomenon was not observed in the other crosses. Plant height for other populations ranged from 1.0 m to 1.3 m and with tiller numbers per plant ranging from 3 to 7, which could be ideal for the upland rice ecology.

7. Yield components

All yield components observed showed a significant variations among the rice populations (Table 3). High percent sterility was recorded in SIK 360 population and SIK 360-1-13-1-2-B

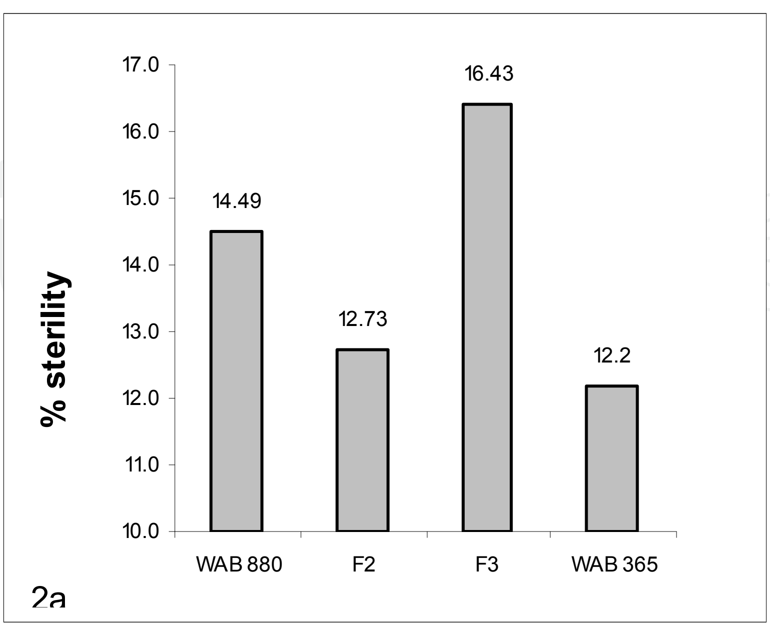
Populations/lines	Generation	Days to Flowering	Shoot dry weight (g)	Plant height (cm)	Tiller number per plant	Vigour
WAB 365-B-1-H1-HB	Parent	87	164.9	103.8	5.5	2.0
WBK 41	F2	87	218.1	108.2	5.5	3.0
WBK 39	F2	89	257.3	121.8	7.0	3.0
WBK 40	F3	89	233.8	116.3	5.0	6.0
WBK 35	F2	89	203.3	111.1	5.5	2.0
NERICA 2	Parent	90	224.5	102.0	5.5	6.0
WBK 64	BC1F2	91	197.6	109.8	5.5	5.0
WBK 106	BC1F2	91	208.4	117.1	5.5	5.0
WBK 150	BC1F2	91	152.1	112.3	3.5	6.0
WBK 39	F3	93	164.6	122.7	5.5	6.0
WAB 450-IBP-6-1-1	Parent	93	244.1	116.9	5.5	5.0
WBK 35	F3	94	166.7	118.8	5.5	4.0
WAB 880-1-38-13-1-P1-HB	Parent	94	243.8	105.2	6.5	5.0
WBK 41	F3	94	174.3	110.9	6.0	6.0
WAB 450-IBP-103-HB	Parent	95	151.6	132.3	4.0	7.0
NERICA 3 (check)	Line	96	196.4	116.7	5.0	4.0
WBK 40	F2	96	225.7	126.9	6.0	6.0
WBK 28	F3	96	171.7	121.4	4.5	5.0
WBK 42	F3	100	197.8	118.7	4.0	5.0
SIK 360-1-B-1-1-4-B	F7	112	333.1	115.5	15.0	1.0
SIK 360-1-B-2-1-2-B	F7	112	182.9	142.9	7.0	6.0
BG-90-2	Parent	115	324.6	94.5	14.5	3.0
SIK 360-1-11-1-1-B	F6	PS	622.0	132.0	20.5	2.0
SIK 360-1-9-1-3-B	F6	PS	612.2	149.6	14.5	1.0
SIK 360-1-B-3-1-11-B	F7	PS	448.0	159.7	9.5	2.0
SIK 360-2-1-4-13-B	F6	PS	479.9	123.5	14.5	1.0
SIK 360-2-1-3-15-B	F6	PS	629.8	137.2	11.5	1.0
SIK 360-1-13-1-2-B	F6	PS	790.5	159.0	12.5	2.0
TOG 5681	Parent	PS	472.7	140.1	21.0	1.0
LSD (0.05)		9.3	158.66	19.21	7.19	2.47
Probability		*	***	***	***	***

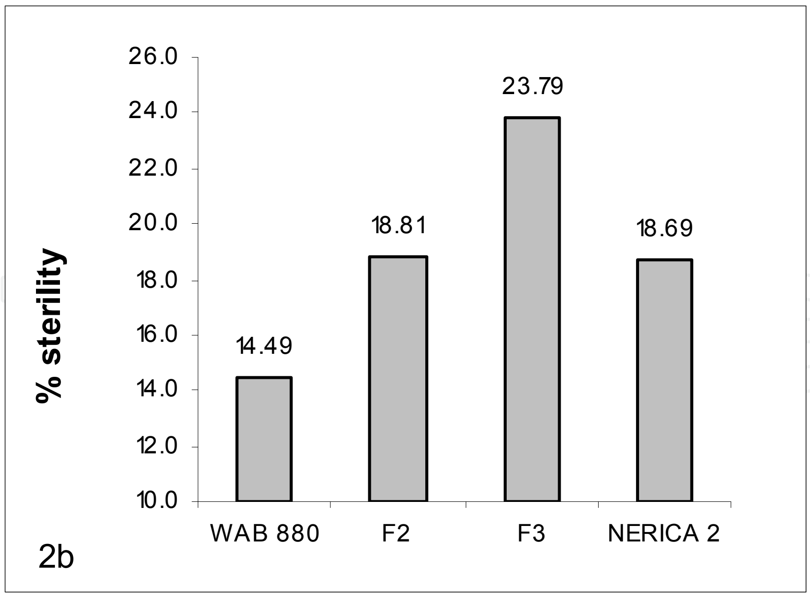
* significant at 0.05 probability level
** significant at 0.01 probability level
*** significant at 0.001 probability level
ns = no significance
PS = Photoperiod sensitive

Table 2. Mean performance of rice populations for some rice characters

had the highest value of 91.51% and WBK 35 with lowest value of 7.41%. All rice populations showed a significant ($P \leq 0.05$) response of effective panicles per square meter, which is higher in SIK 360 lines as compared to the WBK populations. Effective panicles are panicles that bear harvested rice grain. The WBK populations were significantly higher in 1000 grains weight as compared to SIK lines and none of the SIK lines were above the check. The three top best in 1000 grains weight are WAB 880-1-38-13-1-P1-HB, WBK 40 (F3) and WBK 40 (F2) and least is TOG 5681. A significant ($P \leq 0.001$) variation was observed for harvest index (HI) in all the rice populations. The results of harvest index followed similar pattern as with 1000-grain weight among the rice populations. Two parental lines that had the highest harvest index were WAB 365-B-1-H1-HB and NERICA 3 and as well as their progenies, while the SIK 360 lines were low (Table 3). Grain yield significantly varied among the populations and WBK 39 is the highest yielder of 4.35 t ha^{-1}. Six of the entries yielded higher than NERICE 3 (check) and TOG 5681 exhibited the lowest yield.

Higher percentage of sterility was observed in the progenies between crosses of interspecifics than with the cross between intserpecific x *O. sativa* (Figure 2a and 2b). The F3 progenies of the rice populations were observed to be more sterile than their parents and F2 progenies. The F3 progenies were 13.4% and 27.3% more sterile than most sterile parents in the crosses of intersepcific x *O. sativa* (Figure 2a) and interspecific x interspecific (Figure 2b), respectively. This might be due to cytoplsmic differences in each of the crosses. While in the cross between TOG 5681 x BG 90-2, the fertility of progenies increase gradually in each generation due to selection biased toward full grains (Figure 2c). The fertility difference between BG 90-2 and the F7 hybrid is 38.7%, thus, showed that interspecific hybrids require longer generations of selection to restore full fertility. This information has great implication for the development of high yielding interspecific hybrids.





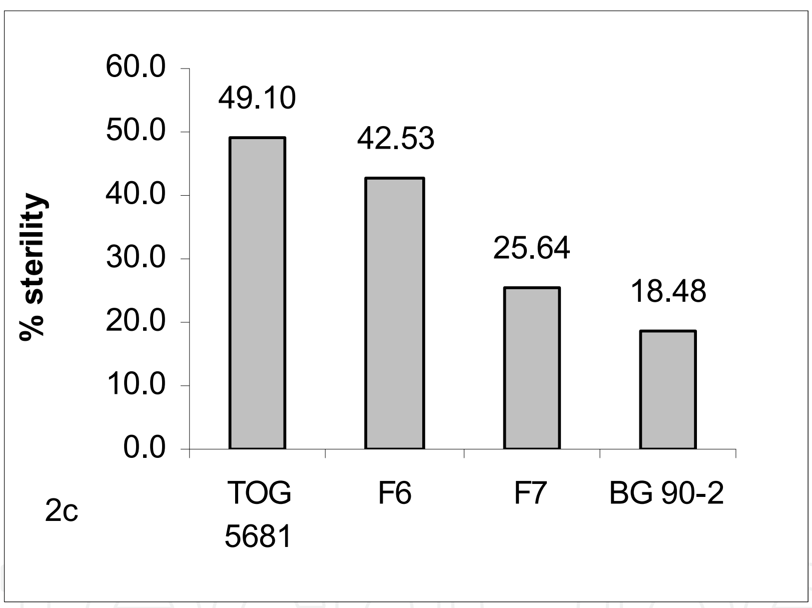


Fig. 2. The effect of sterility in each breeding cycle

8. Relationships among rice traits

Highly significant relationships were observed among all traits except with number of panicles per square meter (Table 4). High grain yield, harvest index and grain to straw ratio were found to be significantly ($P \leq 0.001$) associated with low spikelet sterility. Grain yield had no significant relationship with plant height and tiller numbers at panicle initiation stage. The non-significant relationship observed between tiller number and grain yield could be due to the fact that some tillers died before reaching maturity and also that some tillers were not effective in producing panicles. Percentage sterility was strongly and negatively correlated with yield components examined (Table 4).

Populations/lines	Generation	% Sterility	Number of effective panicles (m^2)	1000 grain weight/g	Harvest index	Yield (t/ha)
WBK 39	F2	12.73	179	32.19	0.47	4.35
BG 90-2	Parent	18.48	198	29.19	0.41	4.18
SIK 360-1-B-1-1-4-B	F7	20.24	271	25.14	0.38	3.85
SIK 360-1-11-1-1-B	F6	16.54	188	25.38	0.28	3.74
SIK 360-1-B-2-1-2-B	F7	35.36	193	28.19	0.41	3.71
WBK 40	F3	15.68	179	34.54	0.48	3.69
NERICA 3 (check)	Parent	9.19	139	28.60	0.50	3.63
WBK 39	F3	16.43	164	31.30	0.49	3.56
WBK 40	F2	19.72	162	34.54	0.47	3.51
SIK 360-1-9-1-3-B	F6	19.53	172	28.57	0.26	3.46
WBK 35	F3	19.59	159	28.77	0.47	3.34
WAB 880-1-38-13-1-P1-HB	Parent	14.49	125	34.86	0.48	3.30
WBK 35	F2	7.41	140	28.63	0.47	3.23
WBK 64	BC1F2	18.52	137	28.77	0.47	3.23
WBK 42	F3	14.68	146	33.40	0.46	3.22
WBK 28	F3	17.95	192	33.03	0.45	3.20
WAB 365-B-1-H1-HB	Parent	12.20	141	26.24	0.50	3.17
WBK 106	BC1F2	14.27	134	29.08	0.48	3.07
SIK 360-1-B-3-1-11-B	F7	21.31	142	22.56	0.25	3.07
NERICA 2	Line	18.69	171	25.83	0.45	3.06
SIK 360-2-1-4-13-B	F6	28.27	168	23.42	0.28	3.01
WAB 450-IBP-6-1-1	Parent	21.07	147	27.46	0.43	3.01
SIK 360-2-1-3-15-B	F6	42.88	245	25.34	0.20	2.84
WAB 450-IBP-103-HB	Parent	14.09	103	32.96	0.44	2.79
WBK 41	F2	18.81	185	30.14	0.41	2.67
WBK 150	BC1F2	21.62	153	31.05	0.45	2.66
WBK 41	F3	23.79	196	27.97	0.43	2.65
SIK 360-1-13-1-2-B	F6	91.51	159	20.88	0.09	1.39
TOG 5681	Parent	49.10	139	19.18	0.05	0.50
LSD (0.05)		19.400	76.903	2.550	0.068	1.315
Probability		***	*	***	***	**

* significant at 0.05 probability level
** significant at 0.01 probability level
*** significant at 0.001 probability level

Table 3. Performance of rice genotypes for some yield components

Traits	Yield	1000gwt	HI	%Sterility	G-S ratio	No.Panicle/ m2	PH
1000gwt	0.375**						
HI	0.576***	0.723***					
%Sterility	-0.620***	-0.495***	-0.720***				
G-S ratio	0.519***	0.694***	0.982***	-0.675***			
No.Panicle/m2	0.352**	-0.247 ns	-0.160 ns	0.057 ns	-0.229 ns		
PH	-0.12 ns	-0.345**	-0.631***	0.457***	-0.612***	0.092 ns	
TN	-0.095 ns	-0.529***	-0.676***	0.282*	-0.674***	0.250 ns	0.395***

* *significant at 0.05 probability level*
** *significant at 0.01 probability level*
*** *significant at 0.001 probability level*
ns: not significant

Note: Yld= grain yield, 1000 grain weight, HI= harvest index, %Sterility, Grain to straw ratio, Pani/m2=Number of panicles /m2, PH= plant height and TN=tiller number at PI stage.

Table 4. Correlation coefficients among traits studied in 30 rice genotypes during 2005 wet season.

9. Performance of single plant progenies

Ten single plant progenies (SPP) were sampled within each plot and analysed (Table 5). Lines from SIK 360 population were higher in shoot dry weight than other populations and SIK 360-1-13-1-2-B had the highest value of 62.88 g. However, SIK 360 lines were lower in grain to straw ratio, harvest index (HI) and panicle harvest index (PHI) than other rice populations. There was significant variation among the populations in response to grain yield. There were 15 entries that yielded above grand mean yield (18.68 g) and six entries that yielded above the check. There was significant relationship between SPP yield and HI ($r = 0.51^{***}$), which could assist in determining the performance of a population at early generations. Plot yield was significantly ($P \leq 0.001$) associated with SPP grain yield and harvest index (Figure 3a and 3b).

10. Discussion

10.1 Phenology in rice population management

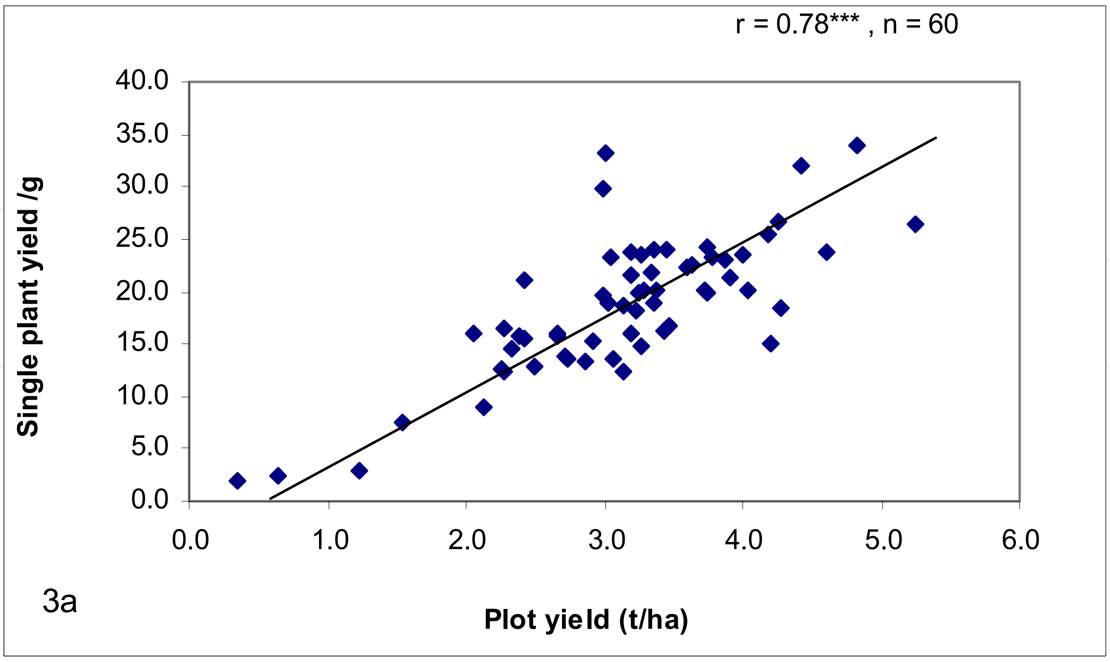
Rice phenology plays an important role in grain yield determination in rice production. Rice varieties of appropriate phenology such as early maturing could be used to avoid adverse drought stress most especially, late season drought (Fukai, 1999 and Fukai and Cooper, 1995). Early flowering populations identified in this experiment were WBK 35, WBK 39,

Populations	Generation	Shoot dry weight /g	Grain: Shoot ratio	Panicle harvest index	Harvest index	Yield /g
SIK 360-1-B-2-1-2-B	F7	37.84	0.80	0.92	0.44	30.88
WBK 39	F2	26.81	0.97	0.95	0.48	25.24
SIK 360-2-1-3-15-B	F6	57.89	0.53	0.90	0.30	24.41
WBK 35	F3	23.08	1.05	0.93	0.48	23.94
SIK 360-1-B-1-1-4-B	F7	34.91	0.68	0.92	0.40	23.59
WBK 40	F3	22.00	1.09	0.92	0.52	22.70
NERICA 3 (check)	Parent	19.87	1.15	0.95	0.53	22.67
WBK 28	F3	24.85	0.93	0.92	0.48	22.61
WBK 39	F3	23.82	0.96	0.93	0.49	22.18
BG 90-2	Parent	32.55	0.69	0.93	0.40	21.81
WBK 35	F2	19.00	1.13	0.95	0.53	21.03
WBK 40	F2	20.32	1.03	0.94	0.49	20.12
WBK 42	F3	20.22	0.97	0.96	0.48	19.86
WAB 450-IBP-103-HB	Parent	22.96	0.82	0.94	0.44	19.80
WAB 365-B-1-H1-HB	Parent	18.20	1.10	0.93	0.50	18.53
WBK 41	F3	20.65	0.88	0.92	0.46	17.90
WBK 106	BC1F2	15.93	1.12	0.93	0.52	17.73
SIK 360-1-B-3-1-11-B	F7	51.42	0.36	0.88	0.26	17.72
WBK 64	BC1F2	18.96	0.96	0.93	0.48	17.52
WAB 450-IBP-6-1-1	Parent	18.08	0.98	0.94	0.49	17.45
SIK 360-1-11-1-1-B	F6	40.89	0.43	0.94	0.30	17.21
WBK 150	BC1F2	20.60	0.86	0.93	0.44	17.12
NERICA 2	Parent	19.50	0.81	0.91	0.45	16.22
WBK 41	F2	19.99	0.83	0.92	0.44	15.38
WAB 880-1-38-13-1-P1-HB	Parent	15.24	1.13	0.91	0.46	14.56
SIK 360-1-9-1-3-B	F6	46.13	0.35	0.93	0.25	14.41
SIK 360-2-1-4-13-B	F6	35.52	0.45	0.92	0.29	14.14
SIK 360-1-13-1-2-B	F6	62.88	0.11	0.83	0.08	5.20
TOG 5681	Parent	59.06	0.04	0.64	0.04	2.17
LSD (0.05)		16.844	0.2927	0.0373	0.0901	9.9103
Probability		***	***	***	***	**

* significant at 0.05 probability level
** significant at 0.01 probability level
*** significant at 0.001 probability level
ns : no significant

Table 5. The performance of single plant progenies in the rice populations.

WBK 40 and WBK 41, which could be suitable for late season drought and may also promote second cropping in some environments. These short duration populations performed favourably in relation to yield as compared to late maturing populations. Their



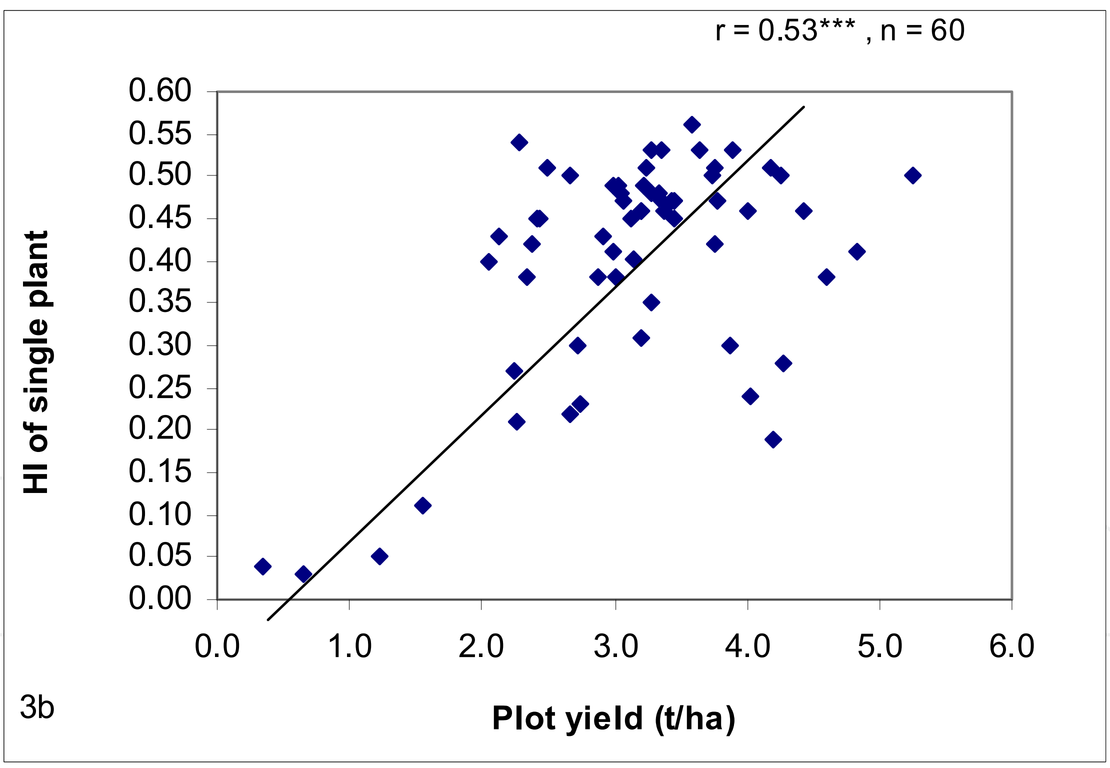


Fig. 3. Relationship between plot yield vs SPP grain yield (3a) and HI (3b) from all populations

favourable yield performance might be attributed to their high harvest index as they are often more efficient in nutrient use than varieties with lower harvest index (Inthapanya et al. 2000). The flowering pattern observed in some of the crosses at each generation might be a good signal in selections to suit differential seasonal planting in some rice ecologies, as farmers do engage in one or more business ventures. This flowering pattern (Figure 1a, 1b and 1c) could be attributed to either effect of epistasis that masked late maturing genes or dominance of early maturing genes in the early generations. As breeding cycle advances, genetic manipulations such as crossing over might occur that unmasked some hidden genes resulting in higher level of segregants (Falconer and Mackay, 1996). This shows that high selection pressure may not be applicable with interspecific hybrids for selecting early maturing materials at the early generations of the breeding cycle.

Most traditional rain-fed lowland rice cultivars are sensitive to photoperiod and later maturing (Mackill et al. 1996). It is believed that they produced higher grain yield than the early maturing rice cultivars as more time is allowed for the plants to utilize more of the available resources and better recovery ability from the early drought (Fukai, 1999). Thus, SIK 360 lines, WBK 39, WBK 40, WAB 450-IBP-6-1-1 and WAB 880-1-38-13-1-P1-HB are identified as potential materials for this ecology.

11. Major agronomic characters in rice population management

The high expressivity of earliness observed in some of the rice populations from early maturing parents (NERICA 2 and WAB 365-B-1-H1-HB) indicates importance of early maturing donors in breeding for early maturity in rice. In West Africa, some communities use rice straws as supplements for animal feeds. Therefore, the loss of shoot biomass from successive generations in breeding cycles implicate rice breeders who will breed for rice straw for these communities in West Africa.

Populations such as SIK 360 lines, WBK 39, WBK 40, WAB 450-IBP-6-1-1 and WAB 880-1-38-13-1-P1-HB could be potential materials for weed competitiveness as they possess high seedling vigour, tillering ability and shoot dry weight characters, which significantly correlate with weed competitiveness in rainfed rice ecologies (Fofana et al. 1995; Dingkuhn et al. 1998).

12. Yield components and associated characters in rice population management

Grain weight is a veritable parameter in rice, in comparison with other cereals (Yoshida, 1981) and 1000 grain- weight is significantly associated with yield components that could be exploited for higher yield. Progenies from WBK populations were higher than the SIK 360 lines in the yield components examined.

Spikelet sterility is significantly negatively correlated with grain yield, as significant variations were observed among the rice populations. Thus, selection of low percentage spikelet sterility in each generation as an indirect method for grain yield selection, which may save time and could be cost effective, this is consistent with the work of Garrity and O'Toole (1994), who found that fertility is related to grain yield in plants that are exposed to drought during flowering. In a related experiment, Lafitte et al., (2006) reported that yield was closely correlated with spikelet fertility (estimated from panicle harvest index (PHI). Yield components in single plant progeny were significantly associated with plot yields, and this could be a rapid way of assessing the performance of rice population in the early generation of the breeding cycle thereby reducing the numbers of material to carryover into the next generation. Lafitte et al., (2006) suggested that highly heritable characters showing high correlations with single plant yield might be used as an indirect selection for yield in early generations such as harvest index for single plant in some of the rice populations.

13. Conclusion

The early maturing rice populations (WBK 35, WBK 39, WBK 40 and WBK 41) identified in this experiment could be deployed in early drought prone environments while the late maturing populations (SIK 360, WBK 42 and BG 90-2) could be suitable for intermittent or terminal drought prone environments. The deployment of these populations to these water stressed environments will increase rice production in the region. The flowering patterns observed, which was attributed to cytoplasmic differences of the parental lines indicates that interspecific hybrids require longer generations of selection to restore full fertility. This information has great implication in the development of high yielding interspecific hybrids. Rice population management is an effective way in fast-tracking development of rice to be deployed to farmers in the region.

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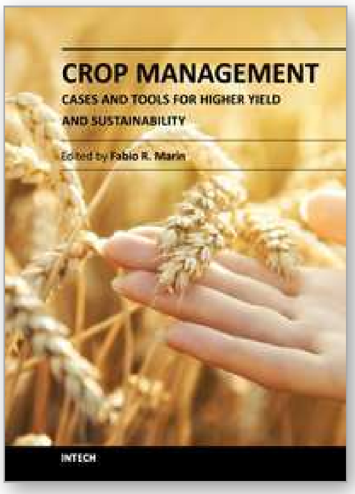

Crop Management - Cases and Tools for Higher Yield and Sustainability
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Agricultural production is related to physical constrains, which may not always be overcomed by technology. However, under the same conditions, it is possible to see well-managed farms consistently making greater profits than similarly structured, neighboring farms. For each abiotical condition, it is well-known there is a difference between the potential and observed yields, which is usually high and often could be reduced through more appropriate management techniques. In this book, we have a selection of agricultural problems encountered in different regions of the world which were addressed using creative solution, offering new approaches for well-known techniques and new tools for old problems.

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