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Response of Recycled Hybrid Maize (*Zea mays* L.) to Diffrent Levels of Nitrogen Application

Mary Grace P. Sola[1], **Joveno S. Lales**[2*], **Gregorio M. Villegas2** and **Alain L. Tagle**[2]

[1]Allied Botanical Assurance, No. 15 21st Avenue
Tagumpay, Cubao, Quezon City
[2]Department of Agronomy, UP Los Baños College
Los Baños, Laguna

Regular usage of hybrid maize seeds places a heavy burden to poor farmers because of their comparatively higher prices compared to that of open pollinated varieties. Hence, they resort to hybrid seed recycling. C-818, a maize hybrid, which is widely grown in the country, was recycled to produce four segregating generations ($F_2 \rightarrow F_5$) for simultaneous nitrogen response evaluation. The objective was to assess the effectiveness of three levels of nitrogen application in mitigating yield depression associated with seed recycling. The experiment was conducted under field conditions using two-factor factorial arrangement in RCBD with four replications. The F_1 generation of C-818 and an improved open pollinated variety, USM 5, were used as check. Each plot was 3 meters wide and 5 meters long with four rows spaced 75 cm apart. The soil in the experimental site is clay loam, slightly acidic (pH 6.3) and has low nitrogen content (0.12%).

Significant variations in plant height, ear height, stalk diameter, number of days to 50% silking and tasseling, maturity, percentage of barren plants, percent ear fill, ear length, ear diameter and 1000-seed weight were attributed to the independent effects of generation and nitrogen application. Differences associated with the three levels of external nitrogen input were insignificant. Significant generation x level of nitrogen interaction was noted in leaf area index and grain yield. Depressions in both traits, which were variably expressed in the four segregating generations, were ineffectively mitigated even at the highest level of nitrogen application. The significant yield depression noted in the study suggests that hybrid seed recycling is not agronomically sound in areas where availability of F_1 seeds is not a production constraint.

Keywords: mitigation, segregating generation, yield depression

Sufficiency level for maize based on local production for the past 20 years has been almost consistently below 100% (BAS, 2001). The trend has been declining for the past 10 years starting from 97% in 1991 to 82% in 2000. Of the four major consumers, the feed industry is the heaviest user accounting for 56.1% of the total requirement in 1991 and increased to 66.3% in 2000.

Forty-six research stations all over the world have invested about 46% of their resources for the production of high yielding varieties (Pandey and

*Corresponding author: jslales@yahoo.com

Gardner, 1992). In the Philippines, locally bred hybrid maize varieties yield about 6 - 8 tons/ha with yield as high as 12 tons/ha attainable under favorable environmental conditions. The national average yield, however, remained low. In 2000, the national average was 1.80 tons/ha (BAS, 2001), which is only 30% of the average yield of local maize hybrids. The gap tends to indicate farmers' inferior crop management practices, which are incompatible with the superior genetic potential of modern maize varieties. Hybrids are known for their high external input requirements for full expression of their genetic potential.

Apparently, regular usage of hybrid F_1 seeds is a heavy burden on the majority of small farmers, compelling them to resort to hybrid seed recycling (i.e., saving seeds from previous harvest for planting in the next season). In developing countries seed recycling is perceived to be cheaper than seed replacement or regular usage of hybrid F_1 seeds (Heisey et al., 1997). Majority of small-scale farmers in Nicaragua prefer hybrid seed recycling due to economic reasons (Ortega-Sequeira et al. 1993). In India, relatively modest yield decline from F_1 generation to the F_2 generation promotes widespread hybrid seed recycling (Singh and Morris, 1997). Farmers in Malawi are contented with the inferior yield of F_2 hybrids hence, wide adoption of seed recycling (Wright and Tyler, 1994).

In the highlands of Mexico, yield depressions in F_2 generations of hybrid maize have been evaluated. Espinosa-Calderon et al. (1990) noted yield depression in single cross hybrids as high as 42% from the F_1 to the F_2 generation while double cross hybrids showed yield depression of about 25%.

Data on yield depression associated with hybrid seed recycling under local conditions are very scanty implying that possible mitigation strategies against yield depression have not likewise been adequately studied. Optimizing the nitrogen status of the plant during critical growth stages, e.g. ear initiation and grain filling could be one practical way to minimize yield depression but the optimum amount of external nitrogen input needed for a specific given agro-climatic condition has yet to be determined. Similarly, the response of segregating hybrid maize generations to nitrogen under local conditions has not been evaluated. This paper presents the results of a field experiment conducted to evaluate hybrid seed recycling-related changes in various traits of C-818 (or DK-818, a commercial hybrid maize), and to determine the response of segregating generations of this hybrid to various levels of nitrogen application.

Materials and Methods

Description of the Experimental Site

The experimental site is well-drained and has been planted to maize twice a year for the past six years. Fallow period between crop cycles is two to three months during which the area is covered with weeds mainly grasses. The soil is clay loam, slightly acidic (pH= 6.3) with low nitrogen content (total N= 0.12%) but has adequate phosphorus and potassium supply (114 ppm and 2.65 cmol(+)/kg soil, respectively). Based on the results of the soil analysis, the recommended fertilizer rate for maize in the experimental site is 130-0-0. .

Treatments and Experimental Design

Twenty-four treatments derived from combining five generations ($F_1 \rightarrow F_5$) of the commercial modified single-cross hybrid, C-818, including an open pollinated variety (USM var. 5) and four levels of nitrogen application (0, 60, 120 and 180 kg N/ha) were randomly assigned to 24 experimental plots arranged in two-factor factorial in Randomized Complete Block Design with four replications. Each field plot was 3 m wide and 5 m long with four rows spaced 0.75 m apart. Individual plants within each row were spaced 0.20 m apart. The open pollinated variety and the F_1 generation of the hybrid were used as check or control.

Production of Advanced Generation Seeds

Advanced ($F_2 \rightarrow F_5$) generation seeds were derived from four crop cycles carried out in 15-m^2 field plots. Foreign sources of pollen around the production area varied from one crop cycle to another. Spatial and time isolation of the F_1 and subsequent segregating generations were not imposed mainly to simulate conditions under which hybrid seed recycling is usually carried out in farmers' fields. Selected ears were obtained from the middle of the field plots.

Cultural Practices

The experimental site was prepared using conventional methods of land preparation for local maize production. Planting was carried out in March 2001 with three seeds sown per hill and thinned to one seedling per hill 10 days after planting. Nitrogen was applied as urea (46% N) in two split dosages, i.e. 50% at planting and the remaining 50% at 21 days after planting. Phosphorus and potassium were all applied at planting as solophos (20% P_2O_5) and muriate of potash (60 kg K_2O), respectively. Irrigation was carried out once a week at weekly intervals. Maximum crop protection was employed to avoid the interference of pest damages on treatment effects.

Measurements

Plant height, ear height, stalk diameter, number of barren plants, number of days from planting to about 50% silking and tasseling, maturity, leaf area index, ear length and diameter, percent ear fill, number of ears per plant, 1000-seed weight, and grain yield were determined within the inner two rows in each plot.

Data were subjected to analysis of variance using SAS software version 6.12. Treatment mean comparisons were carried out using the Least Significant Difference technique. Simple correlation analyses were carried out on selected agronomic traits.

Results and Discussion

General Observations

The results of analysis of variance indicate significant effects of generation and nitrogen and their interaction (Table 1). Differences in plant height, ear height, stalk diameter, number of days from planting to about 50% tasseling and silking, maturity, percentage of barren plants, percent ear fill, ear length, ear diameter and 1000-seed weight were attributed to the individual influences of generation and nitrogen. Significant generation x nitrogen interaction was noted only in leaf area index and grain yield.

Agronomic Traits in Relation to Generation

Segregating generations ($F_2 \rightarrow F_5$) were generally shorter than the F_1 generation (Table 2). Plant height depression ranged from 3.89 cm to 12.16 cm with the highest noted in the F_5 generation. Height reduction in the F_2 population was small and insignificant. Plant height was partially restored in the F_4 generation but not sustained in the F_5 generation.

Simple correlation analyses carried out on plant height and selected yield components show positive and significant relationship between plant height and ear diameter in the F_1, F_2, F_4 and F_5 generations (Table 3) but similar relationship was not noted in the F_3 generation. Plant height was likewise positively and significantly related with ear length in all generations.

Table 1. Analysis of variance of agronomic characters of recycled hybrid maize grown under different levels of N application.

Source of Variation	df	Mean Squares												
		Plant Height (cm)	Ear Height (cm)	Stalk Diameter (cm)	Days to 50% Tasseling	Days to 50% Silking	Days to Maturity	Leaf Area Index	Barren Plants (%)	Ear Fill (%)	Ear Length (cm)	Ear Diameter (cm)	1000 Seed Weight (gm)	Grain Yield (kg/ha)
Generation (A)	5	894.29**	299.68**	0.06*	10.84*	10.84*	10.84*	0.80*	562.46**	116.38**	20.44**	0.91ns	2176.67**	15408919.95**
Nitrogen (B)	3	11840.40**	6868.96**	1.35**	329.80**	329.80**	329.81**	4.75**	1316.34**	157.01**	123.82**	1.36ns	17172.92**	29050684.36**
A x B	15	165.78ns	83.66ns	0.02ns	6.11ns	6.11ns	6.11ns	0.15*	101.21ns	42.96ns	2.19ns	0.55ns	338.75ns	1222605.66**
Error	72	139.12	66.59	0.02	3.35	3.35	3.35	0.07	87.84	27.72	1.83	0.57	195.53	210964.02
C.V. (%)		5.95	8.06	6.95	3.58	3.41	1.77	11.44	47.02	26.66	11.35	19.68	5.75	16.90

* = significant at 0.05% level of significance ** = significant at 0.01% level of significance ns = not significant

Table 2. Effect of hybrid seed recycling on various agronomic traits of C-818.

Variety/ Generation	Plant Height (cm)	Ear Height (cm)	Stalk Diameter (cm)	Days to 50% Tasseling	Days to 50% Silking	Days to Maturity	Barren Plants (%)	LAI	Ear Fill (%)	Ear Length (cm)	Ear Diameter (cm)	1000 Seed weight (gm)	Grain Yield (kg/ha)
F_1 (Check)	202.62	107.81	2.17	51.63	54.12	104.12	9.14	2.66	84.33	13.99	4.22	255.63	4666.10
F_2	195.95	102.24	1.99	51.50	54.00	104.00	25.71	2.16	81.57	11.18	3.79	239.38	2300.50
F_3	190.49	99.22	2.03	52.25	54.75	104.75	22.27	2.05	80.92	11.40	4.09	236.25	2170.40
F_4	198.73	98.88	2.10	50.56	53.06	103.06	19.96	2.43	77.83	12.43	3.67	240.00	2764.50
F_5	190.46	95.42	2.03	50.31	52.81	102.81	17.68	2.22	80.03	11.04	3.67	229.38	2271.00
USM var 5	209.84	103.68	2.04	50.25	52.75	102.75	24.54	2.16	76.84	11.42	3.70	259.38	2131.30
LSD (0.05)	8.32	5.76	0.84	1.29	1.29	1.29	6.61	0.18	3.71	0.78	0.10	9.86	439.24
C.V. (%)	5.95	8.06	19.68	3.58	3.41	1.77	47.03	11.44	26.66	11.35	6.95	5.75	16.90

Table 3. Correlation coefficients of ear diameter, ear length, plant height, stalk diameter and grain yield.

	Ear Diameter					Ear Length					Plant Height					Stalk Diameter				
	F_1	F2	F_3	F_4	F_5	F_1	F_2	F_3	F_4	F_5	F_1	F_2	F_3	F_4	F_5	F_1	F_2	F_3	F_4	F_5
Yield	0.72**	0.85**	0.41ns	0.71**	0.63**	0.81**	0.91**	0.82**	0.89**	0.43ns	0.73**	0.80**	0.76**	0.87**	0.33ns	0.78**	0.57*	0.76**	0.84**	0.39ns
Ear Diameter						0.66**	0.91**	0.45ns	0.92**	0.81**	0.59**	0.67**	0.43ns	0.82**	0.59*	0.68**	0.63**	0.43ns	0.86**	0.79**
Ear Lenght											0.83**	0.81**	0.89**	0.83**	0.81**	0.85**	0.64**	0.91**	0.93**	0.92**
Plant Height																0.94**	0.57**	0.96**	0.89**	0.84**

* = significant at 0.05% level of significance ** = significant at 0.01% level of significance ns = not significant

These findings imply that loss of height uniformity in a population could give rise to highly variable ear size.

Height depression at the crop level does not seem to pose adverse effect on ear size provided that plant height remains uniform. In contrast, the loss of height uniformity as a result of varying rate of growth and development among plants in a population could give rise to wide variability in ear size. Shorter plants are seriously deprived of photosynthetically active radiation, and are, therefore, less capable of producing sufficient amount of dry matter for partitioning into the various organs particularly the ears. Thus, a great number of solar energy-deprived plants in a maize population usually produce nubbins.

Hybrid seed recycling led to significant change in ear height (Table 2). The segregating populations had ears closer to the ground than the F_1 population. Maximum reduction of ear height (12.4 cm) was noted in the F_5 generation. Apparently, the change in ear height was associated with shortening of the internodes below the ear rather than shifting from an upper node to a lower node.

Stalks were significantly thinner in the F_2 and F_3 populations than in the F_1 population (Table 2). A slight recovery was noted in the succeeding generation but was not sustained in the F_5 generation. The instability of this trait may have negative implication on grain yield considering the positive and significant relationship between stalk diameter and grain yield from the F_1 to the F_4, generations (Table 3). In maize, the stalk serves as temporary storage for non-structural carbohydrates that are usually translocated to other organs when supply of fresh assimilates is limited.

The trends in stalk diameter and 1000-seed weight, which seem to be parallel (Table 2), show the importance of stalk diameter as an alternative source of stored non-structural carbohydrates during grain filling. The apparent recovery of stalk diameter in the F_4 generation resulted in partial recovery of 1000-seed weight and grain yield. In contrast, the storage capacity of the stalks of the F_2, F_3 ad F_5 generations appeared to have been substantially reduced resulting in lower 1000 seed weight and grain yield.

Simple correlation analysis likewise revealed that stalk diameter was positively and significantly related with plant height (Table 3). This finding does not, however, necessarily indicate that shorter varieties have thinner stalk than the taller varieties. The importance of stalk diameter-plant height relationship can be more appreciated in a maize population of non-uniform height in which shorter plants usually have thinner stalk. Further correlation analysis show that stalk diameter was positively and significantly related with ear size. This explains the general observation that maize populations of non-uniform height usually give rise to highly variable ear size. At this point, hybrid seed recycling-related yield depression might be attributed to loss of height uniformity, stalk diameter instability and fluctuation of 1000-seed weight.

Examination of individual plants in each plot showed that the percentage of barren plants was significantly higher in segregating populations than in the F_1 population (Table 2). An almost three-fold increase in percentage of barren plants was recorded when F_2 seeds were planted rather than F_1 hybrid seeds. The percentage of barren plants, however, appeared to have decreased as seed recycling progressed although full restoration to the F_1 level was not attained. USM var. 5 had as high a percentage of barren plants as the segregating populations except for the F_5 generation.

Further evaluation of individual plants in each population revealed that the portion of the cob covered with kernels relative to the entire length of the ear (percent ear fill) decreased at varying levels as a result of hybrid seed recycling (Table 2). Significant reduction, however, was noted only in the F_4 generation whereby partial recovery of grain yield was recorded. This observation suggests that deterioration of percent ear fill may not necessarily lead to significant yield depression during hybrid seed recycling.

Segregating generations had significantly shorter ears than the F_1 generation although differences among segregating generations were insignificant except for the F_4 generation in which ear length was significantly longer than those of the other advanced generations. In contrast, variations among generations in terms of ear diameter were insignificant. Stability in this trait can be partly attributed to the fixed number of kernel rows and relatively stable kernel depth.

Seed recycling resulted in significant reduction of 1000-seed weight by 7.6% (Table 2). The trend, however, was not clear in that recovery was apparent in the F_4 generation but was not sustained in the succeeding generation where the highest reduction of 1000-seed weight (10.2%) was noted. Correlation analysis indicates significant relationship between 1000-seed weight and grain yield in the various generations except the F_3 generation in which the degree of association sharply dropped (Table 3) implying the differential magnitude of change that occurs in both parameters during seed recycling.

Response to Nitrogen

Plant populations that depended solely on the inherent nitrogen content of the soil (control) were significantly shorter than those that received external supply of nitrogen (Table 4). Plant height significantly increased with the application of 60 kg N/ha and increased further when the level of application was doubled beyond which height slightly decreased.

To better understand the dynamics of plant height in each generation, height frequency distribution analysis was conducted in which the indicate results the magnitude of plant-to-plant variations in segregating populations varied, depending on the level of nitrogen application (Figure 1). The critical plant height in relation to grain yield and ear size for this hybrid given adequate supply of nitrogen and planted at recommended population density and spacing (other factors held constant) appeared to be about 145 cm. Plants shorter than the critical height were either barren or had small ears (<10 cm long). Barren plants do not contribute at all to crop yield and the more barren plants there are in a population the greater would be the yield depression.

In the absence of nitrogen input, individual plants were short; height uniformity was poor not only in the segregating populations but also in the F_1 population; mutual shading was apparently minimal, and the critical plant height had no distinct bearing on crop yield since leaf area index was quite low (Table 5). The application of 60 kg N/ha remarkably changed both the population mean height and the height frequency distribution. The number of plants below the critical height decreased although the segregating populations had slightly more than the F1 generation and USM var 5. In the F_1 generation, about 3% of the population had a height within the range of 65 cm to 168 cm while the F_2 population had about 20%. The six-fold discrepancy between the two generations may partly account for the significant yield depression noted in the F_2 generation despite the application of nitrogen.

Table 4. Effect of level of nitrogen application on the agronomic traits of C-818,

Nitrogen level	Plant Height (cm)	Ear Height (cm)	Ear Length (cm)	Ear Diameter (cm)	Stalk Diameter (cm)	Barren Plants (%)	LAI	Ear Fill (%)	Days to 50% Tasseling	Days to 50% Silking	Days to Maturity	1000 Seed Weight (gm)	Grain Yield (kg/ha)
0	165.25	76.32	8.82	3.69	1.72	30.62	1.69	76.45	56.17	58.67	108.67	209.38	1257.00
60	203.29	104.88	11.60	3.63	2.08	18.55	2.23	81.04	51.50	54.00	104.00	236.45	2479.20
120	212.12	112.13	13.60	4.12	2.20	13.67	2.48	81.84	48.54	51.04	101.04	256.25	3557.90
180	211.41	111.51	13.63	3.99	2.21	16.89	2.73	81.68	48.13	50.62	100.52	271.25	3575.00
LSD (0.05)	8.32	5.76	0.78	0.84	0.10	6.61	0.15	3.71	1.29	1.29	1.29	5.75	358.64
C.V. (%)	5.95	8.06	11.35	19.68	6.95	47.03	11.44	26.66	3.58	3.41	1.77	9.86	16.90

Table 5. Effect of generation x nitrogen level interaction on leaf area index.

Nitrogen Level	Filial Generation					
	F1	F2	F3	F4	F5	USM Var 5
0	1.85	1.65	1.50	1.75	1.48	1.90
60	2.62	2.10	2.00	2.27	2.18	2.18
120	3.02	2.42	2.22	2.75	2.62	1.90
180	3.15	2.47	2.52	2.95	2.58	2.65

LSD (0.05) = 0.18

C.V. (%). = 11.44

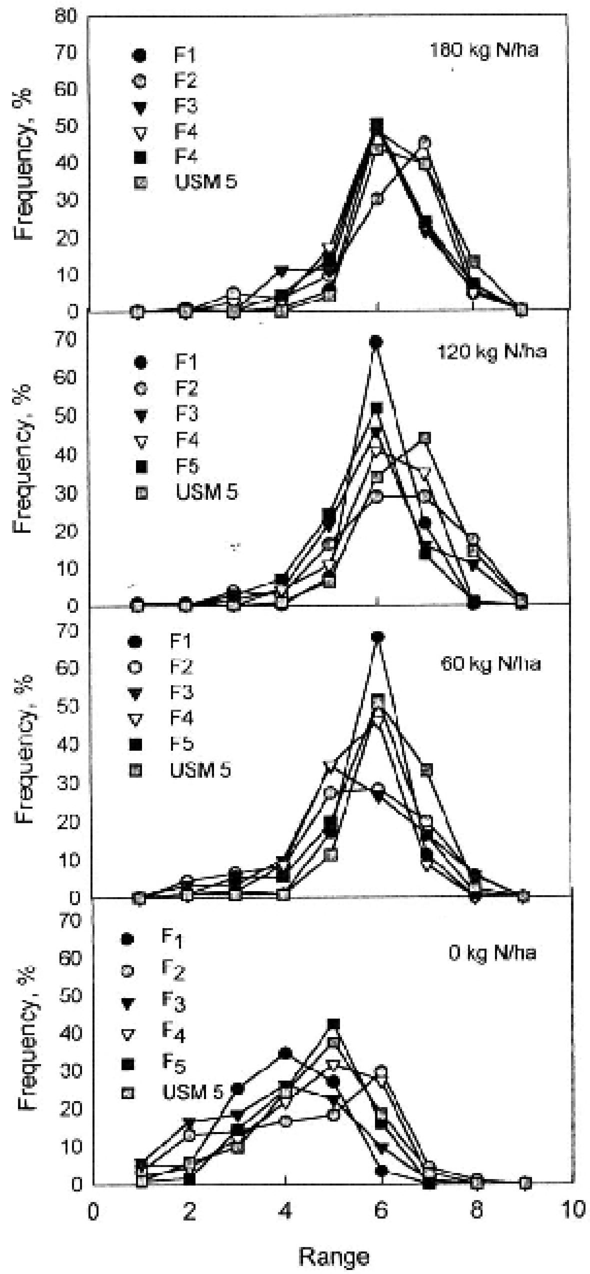

Figure 1. Plant height frequency distribution at different levels of N application. Range 1 = 65-90 cm; 2 = 91-116 cm; 3 = 117-142 cm; 4 = 143-168 cm; 5 = 169-194 cm; 6 = 195-220 cm; 7 = 221-246 cm; 8 = 247-272 cm; and 9 = 273-298 cm.

The application of 120 kg N/ha further decreased the number of plants below the critical plant height both in the F_1 and segregating populations. Similar response to the 180-kg N/ha treatment was noted. Plant height uniformity was neither maintained in the F_1 generation nor restored in the segregating populations at the different levels of nitrogen application. The trend in ear height was similar to that of plant height (Table 4) implying that changes in ear height as a consequence of either hybrid seed recycling or nitrogen application did not involve shifting of ear from an upper node to a lower node. The change was rather associated with either shortening or elongation of internodes below the ear. This observation suggests that significant changes in ear height by shifting from one node to another can be achieved mainly through genetic alteration which did not happen during hybrid seed recycling. Hence, ear height did not directly influence grain yield because source capacity potential, which is a function of the number of leaves or the total functional leaf area above the ear, was not significantly altered. Substantial modification of source capacity potential above the ear takes place when the ear shifts from one node to another.

Stalks became significantly thicker when nitrogen was applied (Table 4) with the highest stalk diameter increment noted in the 120- and 180-kg N/ha treatments. Generation x N level interaction, however, was insignificant indicating that soil nitrogen amendment could not mitigate hybrid seed recycling-related stalk diameter depression particularly in the F_2 generation where the highest reduction (8.3%) of stalk diameter was noted.

Populations that did not receive nitrogen fertilizer attained 50% tasseling and 50% silking stage later by about 7 days than the nitrogen-fertilized populations (Table 4). Worthy to note is the two- to three-day gap between tassel and silk emergence which was maintained across nitrogen treatments. Thus, the enhancing effect of nitrogen application on tasseling and silking did not pose serious implication on pollination. Tasseling and silking were earliest in populations fertilized with either 120 or 180 kg N/ha.

Nitrogen-fertilized populations matured earlier by almost one week than the control (Table 4). Apparently, this was linked to the enhancement of tasseling and silking process which suggests that the grain filling period was neither shortened nor extended. Quite interesting to note, however, is the increasing trend in 1000-seed weight even if the grain filling period was not prolonged despite earlier tassel and silk emergence. This observation indicates that source capacity was not a limiting factor, and that the efficiency of grain filling was likewise high in the fertilized populations. The one-week advancement of crop maturity associated with nitrogen fertilizer application could also be viewed as an escape mechanism that could spare the crop from an impending severe soil moisture stress or other environmental stresses that may occur toward the end of the crop cycle.

The percentage of barren plants was highest in the unfertilized populations (Table 4). Nitrogen application significantly reduced the occurrence of barren plants in populations fertilized with 60 and 120 kg N/ha by 39.4

and 55.4%, respectively. The application of 180 kg N/ha, however, was not as effective as the lower levels of nitrogen application in mitigating the occurrence of barren plants. Nitrogen x generation interaction was not significant indicating that mitigation was not generation-specific.

Majority of the barren plants were laggards starting from the vegetative stage until crop maturity. Worthy to note particularly in the high nitrogen treatment plots, however, were seemingly non-laggard plants but failed to bear a normal ear. These barren plants had thick stalk, large green leaves and as tall as the productive plants. What hindered the ear of these plants from attaining normal size was not clearly understood in this study.

Ear length in plots fertilized with 60, 120 and 180 kg N/ha was significantly higher by 31.5, 54.2 and 54.5%, respectively than in the control in which the average length of ears was 8.82 cm (Table 4). Simple correlation analysis show that ear length was significantly related with grain yield (r2 = 0.81**) and ear weight (r2 = 0.92**). This relationship provides a clue as to how yield depression in segregating populations could be minimized through cultural manipulations like soil nitrogen amendment. Analysis of variance indicates that nitrogen x generation interaction was not significant suggesting that response to nitrogen in terms of ear length was not generation-specific.

Unfertilized populations showed the lowest percentage of ear fill (Table 4). The application of nitrogen, however, significantly reduced the unfilled portion of the ear although 100% ear fill was not attained which indicates that this trait is strongly genetically controlled as manifested by significant differences among generations (Table 2), and stable over a wide range of external nitrogen input.

Significant response to nitrogen in terms of ear diameter was noted only in the 120-kg N/ha treatment (Table 4). The positive response to this level of nitrogen was not clear considering the components of ear diameter (kernel depth and number of kernel rows) which are largely genetically controlled and are apparently not responsive to nitrogen level in the soil.

Nitrogen significantly increased the weight of 1000 seeds by about 22% (Table 4). The highest increment (29%) was noted in populations fertilized with 180 kg N/ha. This observation indicates the potential contribution of changes in this yield component as influenced by soil nitrogen to yield depression. Generation x nitrogen interaction was insignificant implying that the mechanism of mitigating 1000-seed weight depression through soil nitrogen amendment was not exclusive of a particular segregating population.

Generation x Nitrogen Interaction

Leaf Area Index

Variations in leaf area index (LAI) were attributed to the individual effects of generation (Table 2) and nitrogen level (Table 4) and the interaction of the two factors (Table 5). The application of 60 kg N/ha increased LAI by 34.4% across segregating populations with the highest increment (47.3%) noted in the F_5 generation. USM var. 5 showed the least increment (14.7%) in LAI. The F_1 population showed an increase in LAI of 41.6%. Increments in LAI noted in segregating generations associated with the 120-kg N treatment ranged from 46.6% to 77.0% with the highest increment recorded in the F_1 population. A similar trend was noted in the 180-kg N treatment.

The F_1 population consistently showed higher LAI than the segregating generations implying the ineffectiveness of applying nitrogen even at high levels to alleviate the adverse effect of hybrid seed recycling on LAI depression. The response of USM var. 5 to the different levels of nitrogen applied was unpredictable. Recycling C-818 in the absence of external nitrogen input (control) significantly reduced LAI except in the F_4 generation where slight recovery was noted. Recurrence of LAI depression, however, was observed in the succeeding generation. Fluctuations indicate the magnitude of genetic influence on this trait. The highest LAI depression (18.9%) was noted in the F3 generation. The application of 60 kg N/ha did not alleviate seed recycling-related reduction of LAI although the leaf area indices obtained were higher than those recorded in the control. Highest LAI depression was noted in the F_3 generation followed by a slight recovery in the next generation but was still lower by 13.4% than the LAI obtained in the F_1 population. Similar trend was noted in the other N treatments.

LAI generally decreased although slight recovery was noted in the F_4 generation in all levels of nitrogen input evaluated. Full restoration of LAI was not attained due to recurrence of LAI depression in the F_5 generation. Fluctuations of LAI during the course of seed recycling could be partly attributed to variations in the magnitude of out-crossing. Worthy to emphasize at this point the conditions under which the $F_2 \rightarrow F_5$ advanced generations were produced. Four consecutive cropping seasons were needed to produce the four advanced generations and each generation was exposed to different sources of foreign genetic materials. Differential exposure to different sources of foreign genetic contaminants certainly resulted in genetic variations among advanced generations. A similar situation may prevail in farmers' fields where hybrids grown within a small cluster of small farms differ from one farm to another.

The data on LAI indicate that reduction of LAI linked to hybrid recycling could not be mitigated through soil nitrogen enrichment. Substantial reduction of leaf area, which indicates the reduction of canopy photosynthetic capacity of each advanced generation, may lead to the deterioration of ear size, failure of some plants to produce a full-grown ear and eventually yield depression.

Grain Yield

Individual effects of generation (Table 2) and nitrogen level (Table 4) and generation x nitrogen interaction (Table 6) accounted for significant variations in grain yield. Of the four segregating generations, the F_4 population showed the highest response to the application of nitrogen. An average yield increment of about two folds over the control was recorded. The application of 60 kg N/ha significantly increased the yield of the F_2 generation by 79.2%, which was slightly higher than the yield increase noted (76.9%) in the F_5 generation while the yield of the F_4 generation increased by a factor of 2.08. Doubling the rate of nitrogen application increased the yield of the F_2, F_3 and F_4 generations by a factor of 2.56, 3.11 and 3.17, respectively. The F_2 and F_4 generations sustained an increasing response pattern up to the 180-kg N treatment while the F3 and F5 generations showed declining trend beyond the 120-kg N treatment. The highest yield of USM var.5 (2,987 kg/ha) was obtained with the application of 120 kg N/ha.

In the absence of nitrogen input, the highest yield depression (53.1%) associated with hybrid seed recycling was noted in the F_3 generation. The F_5 generation showed the least yield depression indicating yield recovery and tendency to stabilize at an advanced stage of recycling. The F_2 and F_4 populations showed almost the same yield reduction. The application of 60 kg N/ha worsened the scenario except in the F_4 where there appeared a slight yield improvement while the apparent yield recovery noted earlier in the F_5 generation was sustained. Doubling the rate of nitrogen application led further to higher yield depressions except in the F_3 population where a slight improvement was noted. In contrast, the yield of the F_5 generation in the 120-kg N treatment was reduced by 60.2% indicating further deterioration of yield potential despite the high level of nitrogen application. Increasing further the rate of N application did not alleviate the adverse effect of hybrid seed recycling on grain yield. While yield depression in the F_4 generation was slightly decreased, the apparent yield recovery was not sustained in the F_5 generation. Contrary to the findings of Zambezi et al. (1997), which showed alleviation of inbreeding depression through fertilizer application, observations obtained in the present study indicate that nitrogen application was not effective in minimizing yield depression associated with hybrid seed recycling. The results likewise indicate that the open pollinated variety, USM var. 5, as a possible alternative to hybrid seed recycling seemed unreliable. Despite the yield fluctuations noted in advanced generations of C 818, USM var. 5 has not consistently showed significant yield advantage.

Agronomic traits that are closely associated with grain yield were unstable during the course of seed recycling thereby resulting in a yield depression of varying magnitudes in segregating generations of the maize hybrid C 818. While the agronomic response of advanced generations to the 60-kg N/ha treatment was significant, higher levels of nitrogen application were not effective in alleviating the adverse effect of hybrid seed recycling on grain yield. Significant yield depression noted in the study suggests that in areas where seed supply is not a limiting factor, planting F_1 hybrid seeds appears to be more agronomically sound than hybrid seed recycling.

Conclusion

The response of F_1 and segregating generations of C-818 (hybrid maize) to nitrogen manifested in various traits was largely governed by the independent effects of generation and level of nitrogen application. Of the agronomic traits evaluated, only leaf area index and

Table 6. Effect of generation x nitrogen level interaction on grain yield.

Nitrogen Level	Filial Generation					
	F1	F2	F3	F4	F5	USM Var 5
0	2080.24	1129.38	975.83	1139.64	1491.78	725.31
60	4075.73	2024.78	1803.41	2369.91	2640.26	1961.15
120	6303.46	2899.37	3032.41	3618.26	2507.46	2986.73
180	6204.80	3148.53	2869.85	3930.01	2444.48	2852.07

LSD (0.05) = 323.96

C.V. (%) = 16.90

grain yield were influenced by generation x nitrogen interaction. Loss of height uniformity, fluctuations in leaf area index, deterioration of stalk diameter and ear length, increasing number of barren plants and declining 1000-seed weight were hybrid seed recycling-related phenomena that contributed to yield depression. Nitrogen application at different rates did not alleviate yield depression.

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