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Development of High Yielding Synthetic Maize (*Zea mays* L.) Varieties Suitable for Intercropping with Common Bean (*Phaseolus vulgaris* L.)

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Abstract: The objective of the study was to select and develop high yielding synthetic maize variety suitable for intercropping with common bean. S_1 selection method was used to extract lines from Kakamega Striga Tolerant Population (KSTP) maize and Embu population, and the best 10 lines were recombined to form synthetic maize varieties which were evaluated against the KSTP and recommended commercial hybrid (H512) under monoculture and intercropping. The study led to development of two synthetic maize varieties. Egerton synthetic I had the highest light transmission to the ground and gave the highest bean yield (23% reduction over bean monocrop) under intercrop system. It was the best for intercropping with beans. Egerton synthetic II gave the highest maize grain yield (41% yield increase over KSTP). Intercropping Egerton synthetic II with beans offered the highest benefits. There was no significant difference between Egerton synthetic II and H512 in terms of grain yield. The study showed that it is possible to bred genotypes for intercropping system. Intercropping beans with maize selected and bred for intercropping supported transgressive yielding and thus can contributed to food security.

Key words: Synthetic maize, high yielding varieties, intercropping

INTRODUCTION

Maize is one of the most widely cultivated cereal crops in the world. With regard to cultivated area, maize is ranked third after wheat and rice in the world[1] and first in Kenya[2]. In Kenya maize has been and continues to be the major staple food crop for most Kenyans with vast acreage being sown each year by the majority of small-scale farmers throughout the country[3] .

Most of the maize seeds currently in the market in the region are hybrid maize which are costly for the small scale farmers. They perform best under high level of management that is usually beyond the ordinary farmers. Therefore, there is need to develop a high yielding open pollinated variety whose seeds can be recycled by the farmer with minimum loss of yield. Moreover, the hybrid maize varieties in Kenya were specifically bred for monoculture. Unfortunately, the small scale farmers who are now the majority food producers in the country[4], are still using the same maize varieties for intercropping, a system they were not bred for because maize adapted for intercropping has not been developed.

Intercropping is growing of two or more crops simultaneously on the same field or crop intensification in both time and space[5]. Intercropping of maize with beans is more common practice than sole cropping in the tropics and subtropics where small-scale farmers predominate. The most common intercropping regime in Kenya is that of maize and beans[6]. Despite the fact that for a long time intercropping was regarded as primitive practice that would inevitably give way to monoculture, interestingly, the system has not only persisted but also increased and there is now a great interest in intercropping as a means of improving food and livelihood of the resource poor farmers at household level. While in one hand intercropping undoubtedly is a major contributing factor to low bean yields, on the other hand, there are reasons for persistence of this system which are particularly well suited to the needs of small-scale farmers. The challenge therefore is to develop a high yielding open pollinating variety that would not contribute to low yield in a maize-bean intercrop, but would still maintain the inherent stability and risk avoidance needed by the small-scale farmers.

An important aspect of crop production that escapes attention of agronomists and plant breeders is identification of high yielding open pollinated genotypes for the intercropping system because breeders have always been concerned with selections and development of hybrids for sole cropping. In view of the great interest in the intercropping systems within the tropics, there is need to select and develop high yielding open pollinated

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varieties adapted for intercropping system. The broad objective of this study was to make a contribution towards resource poor farmers food and economic security at household level and thereby improve their livelihood. The specific objective of this study was to develop high yielding synthetic maize varieties for intercropping with common bean.

MATERIALS AND METHODS

Original populations and selection procedure: The lines that constituted the synthetic varieties were extracted from Kakamega Striga Tolerance Population (KSTP) and Embu population. KSTP is an open pollinated medium maturing variety developed by Kenya Agricultural Research Institute (KARI) from a collection of Kenya local landraces which have been grown in striga (*Striga hermonthica*) infested fields long enough to acquire good level of striga tolerance. Embu population was developed from two populations, Embu I and Embu II. Embu I was developed by pooling together medium maturing Kenya local landraces. While Embu II was developed by pooling together medium maturing materials from Central America.

S_1 selection method was applied to select lines from KSTP and Embu population. Suitable individual plants based on plant architecture, viguor and prolificacy were selected from the base populations and selfed. Identification of genotypes compatible with intercropping was done by measuring plant height, mean leaf angle, number of leaves per plant and leaf area index[7]. Leaf angle was the major selection criteria and only plants with less than 30° mean leaf angle were selected[7] The selected lines were tested in replicated trials under intercropping and the best 10 lines were identified, diallel crosses without reciprocal crossing, were made and tested for high combining ability[7]. The diallel analysis was performed for the crosses according to model II of Griffings[8]. Method II which involves parents and one set of F_1's without reciprocal crosses was used.

Development of the synthetic maize: On the basis of general and specific combining ability for plant height, leaf angle and grain yield, two synthetics maize varieties (Egerton synthetic I and Egerton synthetic II) were formed[7,9]. Each synthetic maize variety was constituted by intermating five S_1 lines in isolation from one another either by distance or time. The selection of the 5 lines was based on their combining ability for leaf angle, plant height and grain yield[7,9].

Evaluation of synthetic maize varieties: Field experiments were conducted at Egerton University, Njoro, Kenya for two growing seasons. The two synthetic maize varieties were evaluated against the KSTP and recommended commercial hybrid (H512) under monoculture and intercropping.

Evaluation and experimental design: The two synthetic maize varieties were evaluated in split-plot design in Randomised Complete Block Design (RCBD) with 3 replicates. The main plots were split into intercropping and monoculture and the subplots were split into synthetic maize varieties, KSTP and H512. The maize for intercropping was planted with beans (*Phaseolus vulgaris* L.). Maize was planted at spacing of 75 cm between the rows and 30 cm between plants within the rows. The intercropped beans was planted between rows of maize plants at 37.5 cm from maize row and spacing between bean plants within rows was 15 cm. Both beans and maize were planted simultaneously. Maize for monoculture (pure stand) was planted at spacing of 75 cm between rows and 30 cm between plants within the rows. Beans for monoculture were planted at spacing of 45 cm between bean rows and 15 cm between plants within the rows. Weeding was carried out mannual using a hoe. Maize and beans were planted with diammonium phosphate (DAP) at an equivalent rate of 70 kg P_2O_5 ha^{-1}. The maize was topdressed using Calcium Ammonium Nitrate (CAN) at an equivalent rate of 60 kg N ha^{-1} at V6 phenological stage.

At planting two seed were placed per hill and 10 days after emergence, the stands were thinned to one plant per hill. For the intercropping, there were 7 rows of maize and 6 rows of beans per plot. The rows of maize and beans on both sides of the plot acted as guard rows while the middle 5 rows of maize and 4 rows of beans were experimental. For pure stand, there were 7 rows of maize and 6 rows of beans per plot. The rows of maize and beans on both sides of plot acted as guard rows while the middle 5 rows of maize and 4 rows of beans were experimental. The parameters observed/ measured on this study were: (I) plant height, (ii) ear height, (iii) mean leaf angle at 50% flowering, (iv) number of leaves per plant, (v) leaf area index, (vi) 50% maturity, (vii) shelling percentage (viii), cob length, (ix) cob diameter, (x) number of grains per line, (xi) number of lines per cob (xii), 100 seed-weight and (xiii) grain yield.

Data collection

Maize: Stand count was determined 10 days. Generally, Plant height, ear height, leaf area index, leaf angle and number of leaves per plant were recorded from 10 randomly selected maize plants in each plot. Days to flowering and days to maturity were recorded when 50% of plants have flowered or cobs matured, respectively.

The height of plant was measured as the distance from soil surface to the horizontal-most section of the maize tassel. Light transmission in the canopy was measured using sunscan canopy analyser. Leaf area index was determined during the active growth period of maize to assess the leaf cover on ground. The leaf area index was determined using the formula:

Leaf area = leaf length * leaf diameter at the mid of the leaf

LAI=∑ ((0.75 *leaf area/spacing)); from I=1 to n=number of leaves/plant (1)

Leaf angle per plant was determined physically using a protractor. Leaf angle was taken as the vertical distance between the stalk and leaf. Measurements were carried out at three stages, at flowering initiation, 50% flowering, and at the end of flowering. At maturity the cobs were harvested, oven dried at 70°C, grains shelled and grain yield taken at 12-13% moisture content on plot basis. Grain yield was obtained by harvesting all the experimental plants in each plot. 100-seed weight from 100 randomly selected seeds from the bulk in each plot was recorded.

Beans: Plant height, number of branches per plant, number of pods per plant and number of seeds per pod were recorded from 10 randomly selected bean plants in each plot and 10 randomly selected pods from the 10 randomly selected bean plants, respectively. Bean seed yield at 12% moisture and 100-seeds weight was recorded. 100-seed weight from 100 randomly selected seeds from the bulk in each plot was recorded. Days to flowering were recorded when 50% of plants have one or more flower (R6). While days to maturity were recorded when 50% of plants have reached physiological maturity (R9). At maturity grain were harvested from all the experimental plants in each plot, oven dried at 70°C and grain weight taken at 12-13% moisture content on plot basis.

The yields of beans and maize were used to calculate Land Equivalent Ratios (LERs) according to International Rice Research Institute (IRRI)[10]. Partial LER (individual crop's LER) and total LER (sum of individual crop's LER) were used as indices to evaluate the productivity of intercrop system.

Data analysis: Data was analysed using MSTAT program for analysis of variance and Fisher's LSD at ($p<0.05$) was calculated to compare treatment means[11]. Land Equivalent Ratio (LER) was also calculated to determine the comparative productivity of a unit area of land under intercropping and monoculture.

RESULTS AND DISCUSSION

Maize: There was no significant difference ($p<0.05$) among the cropping system and maize genotype x cropping system interactions for all characters studied, indicating that maize performance in both monoculture and intercropping system does not differ markedly. One possible explanation was that maize is a dominant component in a maize-bean intercrop. Leaf display is the key to maize dominance in the intercrop with bean. The restricted extension potential of the bush bean is ill suited to competing with the vertically oriented maize growth. The initial phase of mutually negative interaction between the two components ended when the vertical extension of the maize stalk resulted in an overtopping of the bean by maize canopy. Subsequent maize growth paralleled that of the monocrop maize. Therefore, the competitive balance was unequal and the performance from the increasingly dominant maize approached that achieved by the monocrop maize.

Significance difference ($p<0.05$) among the synthetic maize varieties, commercial hybrid and KSTP for all traits under study was observed (Table 1 and 2). The results showed that the base populations were responsive to selection.

Light transmission was higher in Egerton synthetic I (1146.90 μmol m^{-2} S^{-2}) and was lowest in H614 (493.62 μmol m^{-2} S^{-2}) (Table 3). It was evident that leaf angle affect the amount of light transmitted in a maize crop. Several studies have shown that radiation interception is influenced by several architectural attributes, including leaf orientation[12-16]. Light interception by canopy increases as the leaf orientation to horizontal increases thus decreasing the maximum potential photosynthesis by self shading. Therefore, breeding for more erect oriented leaves may increase the net photosynthesis and ultimately the yield of the plant. Furthermore, erect oriented leaves will allow more transmission of light to the understorey crop and thus can lead to transgressive yielding. The highest light penetration to the ground was obtained in the Egerton synthetic I while the lowest was obtained in H614. This indicates that more erect-leaf results in more light penetration and thus less light interception. The higher LAI and aggregated foliage distribution associated with H614 would cause increased foliage overlap and foliage self shading, thus reducing light transmission into the lower canopy.

Maize grain yield in monoculture and intercropping system did not differ significantly ($p<0.05$). However, maize yield was relatively higher in monoculture than in

Table 1: The effect of selection on maize grain yield and other architectural and agronomic characters at Egerton University in 2002

Treatments	Q1	DTF	PH	EH	NL/P	LAI	CL	CD	GY
Egerton synthetic I	19.02	103.80	178.15	92.07	13.42	3.65	21.28	3.67	5222.36
Egerton synthetic II	24.11	103.80	225.37	111.22	15.06	4.80	34.91	3.95	5604.57
KSTP	33.95	105.20	212.62	108.63	13.16	4.00	21.40	3.28	3989.98
H512	34.12	101.25	215.33	112.67	16.67	4.90	33.45	3.96	5820.42
$LSD_{0.05}$	4.05	1.11	11.67	7.20	0.77	0.32	3.65	0.46	219.10

GY = grain yield, DTF = days to 50% flowering, Q1 = mean leaf angle at 50% flowering, PH =plant height, EH = ear height, NL/P = number of leaves/ plant, LAI = l eaf area index, CL = Cob length and CD = Cob diameter Grain yield (GY) presented is for monoculture

Table 2: The effect of selection on maize grain yield and other architectural and agronomic characters at Egerton University in 2003

Treatments	Q1	DTF	PH	EH	NL/P	LAI	CL	CD	GY
Egerton synthetic I	19.96	103.10	184.45	88.42	12.99	3.90	22.01	3.49	5175.0
Egerton synthetic II	22.86	104.3	218.87	113.56	15.42	4.82	35.04	3.85	5686.5
KSTP	35.93	106.10	220.11	112.25	12.98	4.12	20.98	3.09	4085.7
H512	37.54	102.01	219.49	110.35	17.00	4.91	34.24	4.00	5780.0
$LSD_{0.05}$	3.95	1.07	9.64	9.88	0.81	0.45	2.14	0.73	179.0

GY = grain yield, DTF = days to 50% flowering, Q1 = mean leaf angle at 50% flowering, PH =plant height, EH = ear height, NL/P = number of leaves/ plant, LAI = leaf area index, CL = Cob length and CD = Cob diameter Grain yield (GY) presented is for monoculture

Table 3: The effect of selection on phenotypic traits and light distribution in maize at Egerton University in 2002/2003 †

	Varieties			Radiations μmol m^{-2} s^{-1}		
Treatments	DTF	ø	LAI	Incident	Trans-mitted	Reflected/ Intercept
Egerton synthetic I	103.10	19.49	3.78	1383.5	1146.9	236.6
Egerton synthetic II	104.05	23.49	4.82	1436.2	1075.8	360.4
KSTP	105.65	34.94	4.12	1218.8	637.5	580.6
H512	101.63	35.41	4.91	1404.5	514.8	889.7
H614	119.7	41.67	5.00	1406.9	493.6	913.2

DTF = days to 50% flowering, ø = mean leaf angle at 50% flowering and LAI = leaf area index †Based on means across the two growing seasons (2002 and 2003) H614 is a very popular hybrid in Kenya. It was included because it has been shown to have very high shading effects on beans

Table 4: Effect of selection on maize grain yield at Egerton University in 2002/2003 †

Treatments	Maize monocrop	Maize intercrop	Percent monocrop over intercrop	Percent over KSPT	Percent over H512
Egerton synthetic I	5198.68	5069.70	98.0	126.7	89.2
Egerton synthetic II	5645.54	5590.60	99.0	139.2	98.5
KSTP	4037.84	3934.30	96.4	100.0	-
H512	5800.21	5645.00	97.3	-	100.0

† Based on means across the two growing seasons (2002 and 2003)

intercrop system (Table 3), indicating that maize does not possess complete dominance over beans. There is still some degree of interspecific competition between the two crop component of the intercrop system for the available resources (PAR, nutrients space and water).

Average percentage increase in yield for Egerton synthetic I and Egerton synthetic II (taking KSTP = 100%) were 126.7 and 139.2%, respectively. However, while taking H512 (a hybrid) = 100%, the average percentages were 89.2 and 98.5% for Egerton synthetic I and Egerton synthetic II, respectively (Table 4). This increase in yield can be attributed partly due to heterotic group pairings and presumably partly due to increased light penetration since the developed synthetics have more erect-leaf orientation compared to KSTP. With more erect-leaf, penetration of sunlight into the canopy should result, thus increasing the total leaf area receiving the greater light intensity and reducing the number of parasitic leaves. The source capacity is increased resulting in more photosynthetic activity and greater production of dry matter and eventually grain. Loomis and Connor[17] found that canopy architecture determines the interception of solar radiation by the crop and the distribution of irradiance among individual leaves and component the crop(s). It was worthy noting that there was no significant difference ($p<0.05$) difference between Egerton synthetic II, a synthetic variety, and H512, a hybrid variety, in terms of grain yield (Table 1 and 2). This could be partly attributed to the more erectophile leaves of Egerton synthetic II compared to those of H512. The more erectophile leaves will allow more light to the lower canopies and thus increased net photosynthesis and ultimately the yield of the plant.

The importance of canopy architecture and leaf response to photosynthesis has been described by Davidson and Philip[18]. Canopies with planophiles leaves (large k) receive high irradiance on the top leaves, which, with small vertical distribution of gross photosynthesis are increasingly light saturated. Canopies with erectophile displayed leaves (small k) have more even distribution of low irradiance over their leaf surface (cosine law) and hence less light saturation and higher photosynthesis per unit of intercepted radiation at any value of vertical distribution of gross photosynthesis. This could partly explain why the maize synthetics, which had more erectophile leaves gave higher yields despite having lower LAI compared to KSTP. Higher LAI and aggregated foliage distribution associated with KSTP would cause increased foliage overlap, and foliage self shading thus reducing light capture efficiency and quality of light intercepted by crops.

Table 5: The effect of selection of maize on bean grain yield at Egerton University in 2002/2003 †

Treatments	Beans	% mono	DTF	NB/P	NP/P	100SW	PH
Monocrop	2134.4	100.0	65.2	3.80	16.20	35.90	45.90
Egerton synthetic I/bean	1648.4	77.2	67.3	3.70	13.20	35.70	44.90
Egerton synthetic II/bean	1600.2	75.0	67.9	3.70	13.40	35.10	45.20
KSTP/bean	1257.6	59.0	69.0	3.00	9.60	34.80	44.70
H614/bean	1031.4	48.3	71.2	2.70	8.20	31.20	49.00
$LSD_{0.05}$	179.0			0.01	0.69	1.12	1.09

Mono = moncrop, DTF = days of flowering, NB/P = number of branches per plant, NP/P = number of pods per plant,
100sw = 100 seed weight and PH = plant height
†Based on means across the two growing seasons (2002 and 2003)

Therefore, modification of canopy geometry is an important consideration when developing varieties for intercropping system as well as high yielding. Loomis and Connor[17] suggested that canopies bred for increased light penetration to lower leaves in cotton give higher yields. If the penetration of light into canopy increases in proportion to the decrease of the leaf angle from the vertical, there should be an increase in photosynthesis. Greater photosynthesis means increase in production of dry matter, part of which should be converted to grain. Pandleton *et al.*[19] found a yield increase of 14% when leaves above the ear of pioneer 3306 were tied upright during pollination at about 10° from vertical and maintained in this position until harvest compared with the untreated check. The data from this research supports this finding and can be used as the evidence of the optimum leaf angle to be developed in maize for maximum grain production. Meanwhile, the data generated from this particular study, suggest that the maize breeder should select for both plant types, environmental factors and their interactions as grain yield is a function of the total phenotype, and leaf angle is only one phenotypic trait that affects grain production.

Bean: There was significant difference ($p<0.05$) among different bean treatments for all traits under study (Table 5). The highest yields of 2134.4 kg ha^{-1} was obtained when bean was planted in sole crop, while the lowest yield of 1031.4 kg ha^{-1} was obtained when beans were intercropped with H614. The plant height ranged from 44.7 cm (KSTP -bean intercrop) to 49.0 cm (H614-bean intercrop). Number of branches per plant ranged from 2.7 (H614-Bean intercrop) to 3.8 (bean sole crop). Days to 50% flowering raged from 65.2 days (bean monocrop) to 71.2 days (H614-bean intercrop). Number of pods per plant ranged from 8.2 (H614 bean intercrop) to 16.2 (bean monocrop) while 100 seeds weight ranged from 31.2 (H614 bean intercrop) to 35.9 (bean monocrop) (Table 5). Beans under H614 were taller, had few branches and mature late, whereas sole beans matured early, had more branches and were shorter. These results can be attributed to difference in leaf angle for different maize genotypes used in the maize-bean intercrop. The difference in canopy architecture results in different radiation transmitted to the understorey bean crop. Therefore, light intensity at the level of the understorey crop was different for different maize genotypes. Decreased leaf angle to vertical was associated with concomitant increase in light penetration. The difference in light intensity reaching the understorey crop would lead to the difference in growth and accumulation dry matter and eventually grain yield.

The performance of beans was clearly affected by the maize intercrop component. There was decrease in performance of all traits under study except days to flowering (Table 5). This could be attributed to sink limitation to photosynthesis. This occurs when the ability of the source is limited by the competition for environmental resources. One possible explanation for delayed flowering and bigger plants in H614 was that due to competition for light, bean plants remained vegetative for longer periods than those which encountered less competition and as such a great proportion of leaves not necessarily active in photosynthesis.

In all cases bean seed yield was reduced compared to sole cropping. Average yield (taking sole crop = 100%), ranged from 48.3% (H614-bean intercrop) to 77.2% (Egerton synthetic I/bean intercrop) (Table 5). Clark[20] found a yield decrease by 40% of bush beans in maize-bean intercrop while Fininsa[21] found a reduction of 67%. Willey and Osiru[22], Dagnew[23] have also reported yield reduction for both maize and beans in a maize -beans intercrop system. Since bean yield tends to decrease with decrease in light transmission it can be inferred that the yield of beans were reduced because of shading. The greater reduction (51.7%) was obtained when intercropped with H614 (1031.37 kg ha^{-1}). H614 had the least light transmission of 493.62 umol m^{-2} S^{-2} (Table 2).

Competition for light has been considered one of the major factors contributing towards reduction in yield and growth of plants in polycultures. Using additive and substitutive designs, Trenbath and Harper[24] found that shading affected the pattern of growth of *Avena* species used as indicators in interspecific mixtures. Lockhart[25] showed that the slow growth of pinto beans at low light intensity was due to a deficiency of photosynthetic products.

Clearly, intercropping with bean can successfully exploit underutilized early season resources and contribute to transgressive yielding only if the bean does not directly compete with the maize during later growth. The critical point is the accessibility of the intercrop to resources which were available, but unutilized by seedling

Table 6: Productivity and economic returns of intercropping in 2002/2003 †

Treatments	Land Equivalent Ratio (LER)		
Intercropped genotype	Productivity		
	Partial LER		
	Bean	Maize	Total LER
Egerton synthetic I	0.77	0.98	1.75
Egerton synthetic II	0.75	0.99	1.74
KSTP	0.59	0.96	1.55
H614	0.48	1.01	1.49

†Based on means across the two growing seasons (2002 and 2003)

maize. These resources can support transgressive yielding, however, only if the bean yield contribution is not exceeded by a corresponding maize yield loss. The specific competition balance attained by the bean and the maize determines not only the individual yield of each component but total system yields as well. Shifting the balance of resources use between the bean and maize by means of modification in maize canopy structure clearly demonstrates that highest yields of beans were attained when the dominant maize had the smallest leaf angle. Thus resulting in higher light transmission to the understorey beans.

Productivity of Intercropping: Data presented in Table 6 indicate that intercropping beans with maize increases food production per unit area. Productivity of intercropping was evaluated using partial and total LERs as indices. Partial and total LERs for maize and bean intercropping are shown in Table 4 and both LERs for associate crops under the intercropping varied significantly ($p<0.05$). Partial LERs for the crops in the intercropped system are less than one. In the intercropping Egerton synthetic I with beans the total LER indicates about 75% (highest) relative yield advantage while that of H614-beans indicated about 49% (lowest) relative advantage. The productivity of beans/maize intercropping as determined by total LER, in all combinations, was superior in resource use efficiently compared to sole cropping. However, in H614, bean produced only the equivalent of 48% of its sole crop yield while 77% was attained in Egerton synthetic I. Similarly, the equivalent of 101 percent and 96%, maize sole crop yield was harvested when H614 and KSTP were grown in an intercrop system respectively. The bean-maize intercropping system increased the overall productivity. This cereal/legume intercropping could benefit smallholder through generating sustainable income, minimizing risk of crop failure and providing a source of protein diet. Future study should investigate the performance of indeterminate beans. Moreover, the effects of intercropping system on the associate crops pathosystem and insects pests deserve research attention.

The study has shown that with proper selection of crops and breeding genotypes for specific niches, food production can be greatly increased. Breeding for more erectophile leaves can result in high yielding varieties which can be grown either as monoculture or intercrop depending on the choice of the farmer. The differences noted between bean intercrops were attributed to differences in light transmission to the understorey bean crop. Therefore, modification of canopy geometry is an important consideration when developing varieties for intercropping system as well as high yielding varieties. It is therefore recommended that the procedure adopted in this particular study be applied to improve the plant geometry of hybrid parental lines before they are used in the production of hybrids for two reasons (I) to make them suitable for intercropping and (ii) improve their yields. This study has shown that in addition to the usual components of grain yield, focussing selection on photosynthetic apparatus achieved rapid progress in yield improvement. The study recommends large scale evaluation and assessments of the developed synthetic maize varieties against the KSTP and commercial hybrids in the market in medium agro-ecological zone in the region.

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REFERENCES

1. International Maize and Wheat Improvement Centre (CIMMYT), 1990. 1998/90 CIMMYT world maize facts and trends: Realising the Potential of maize in sub-saharan Africa. Mexico, D. F.: CIMMYT.
2. Kimurto, P.K., 2000. Selection of breed wheat (*Triticum aestivum* L.) varieties for marginal areas of Kenya by stimulating drought stress. M.Sc Thesis. Egerton University.
3. Gichuhi, G.J.M., 1982. Kenyan maize and wheat acreage responses: an econometric study of the large farm sector. M.Sc Thesis, Pennsylvania State University.

4. Nyoro, J.K., 2002. Kenya's competitiveness in domestic maize production: Implications for food security. A paper presented in a seminar at the African study centre, University of Leiden, on 7th November 2002.
5. Andrew, D.J. and A.A. Kassam, 1975. The importance of multiple cropping in increasing world food supply (ICRISAT Hyderbad, India). Paper read to the American Society of Agronomy. Aug., 26: 1975.
6. Mungai, S.G., 1986 Characterisation of ideal bean (*Phaseolus vulgaris* L.) genotype for intercropping. M.Sc Thesis. University of Nairobi.
7. Muraya, M.M., C.M. Ndirangu and E.O. Omolo, 2005. Heterosis and combining ability in a diallel crosses involving maize (*Zea mays* L.) s_1 lines. Australian J. Exptl. Agric.
8. Muraya, M.M., E.O. Omolo and C.M. Ndirangu, 2003. Development of high yielding synthetic maize (*Zea mays* L) varieties for medium agro-ecological zones. In Proceedings of European Union/Kenya Agricultural Research Institute (KARI) symposium held at KARI headquarters, Nairobi, on 1st-4th Dec., 2003.
9. Griffing, B., 1956 Concept of general and specific combining ability in relation to diallel crossing systems. Australian J. Biol. Sci., 9: 463-493.
10. IRRI (International Rice Research Institute), 1974. Annual report for 1973. IRRI, Los Banos.
11. Steel, R.G.D. and J.H. Torrie, 1980. Principles and procedures of statistics: a biometrics approach. Mc Graw-Hill publishing company, New York.
12. Duncan, W.G., 1971. Leaf angles, leaf areas, and canopy photosynthesis. Crop Sci., 11: 482-485.
13. McCree, M.J. and M.E. Keener, 1974. Simulations of the photosynthetic rates of three selections of grain sorgum with extreme leaf angles. Crop Sci., 14: 584-588.
14. McMillen, G.G. and J.H. McClendon, 1979. Leaf angle: An adaptive feature of sun and shade leaves. Botany, 140: 437-440.
15. Oker-Blom, P. and S. Kellomdki, 1982. Effect of angular distribution of foliage on light absorption and photosynthesis in plant canopy: *Theoretical computations,* Agricl. Meteorol., 26: 105-108.
16. Werk, K.S. and J.R. Ehleringer, 1984. Non-random leaf orientation in *Lactuca serriola* L. Plant cell Environ., 7: 81-84.
17. Loomis, R.S. and D.J. Connor, 1992. Crop ecology: Productivity and management in agricultural systems. Cambridge University press, Cambridge.
18. Davidson, J.L. and J.R. Phillip, 1958. Light and pasture growth. Arid Zones Res., 11: 181 -187.
19. Pendleton, J.W., G.E. Smith, S.R. Winter and T.J. Johnson, 1968. Field investigations of the relationship of leaf angle in corn (*Zea mays* L.) to grain yield and apparent photosynthesis. Agron. J., 60: 422-424.
20. Clark, E.A., 1980. Physiological basis for transgresive yielding in bean-maize intercrop. Ph.D Thesis, Iowa State University.
21. Fininsa, C., 1997. Effects of planting pattern, relative planting date and intra-row spacing on a haricot bean/maize intercrop. African Crop Sci. J., 5: 15-22.
22. Willey, R.W. and D.S.O. Osiru, 1972. Studies on mixture of beans (*Phaseolus vulgaris* L.) with particular reference to plant population. J. Agricl. Sci., 79: 517-529.
23. Dagnew, G., 1981. Effect of intercropping on yield, yield components and relative yield totals of the associated maize and bean, *Phaseolus vulgaris* L. M.Sc Thesis, Addis Ababa University, Ethiopia.
24. Trenbath, B.R. and J.L. Harper, 1973. Neighbour effects in genus *Avena*. I. Comparison of crop species. J. Applied Ecol., 10: 379-400.
25. Lockhart, J.A., 1961. Photoinhibition of stem elongation by full solar radiation. American J. Bot., 48: 387-392.