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Effects of genotype on yield and yield component of soybean (*Glycine max* (L) Merrill)

Liberatus Dominick Lyimo[1*], Musa Rashid Tamba[2,3] and Richard Raphael Madege[3]

[1]School of Biological Sciences, University of Dodoma, Box 338 Dodoma, Tanzania.
[2]Ilonga Agricultural Research institute, Legume unit,Box 33 Kilosa-Morogoro, Tanzania.
[3]Department of Crop Science and Horticulture, Sokoine University of Agriculture, P. O. Box 3005, Morogoro, Tanzania.

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In 2013, the multi-location trial was implemented to evaluate the new soybean genotypes for their agronomic performance against the local check. The experiment was conducted in three locations namely Ilonga, Kibaha, and Mlingano in each location a triplicated trial involving six genotypes of soybeans were implemented. The effects of genotype, location and genotype x environment interaction under combined analysis on agronomic yield, and soybean yield were found significant at P<0.05. The highest mean yield was found from TGX 1954-1Fand TGX 1908-8F in all locations. Correlations coefficient for seed yield revealed a positive and significant association with all agronomic yield except 100 seed weight in all locations. The phenotypic coefficient of variation and genotypic coefficient of variation estimates were significantly high for pods per plants (49.49/27.04), while crude protein had the lowest values (1.45/0.98). The finding also revealed that the differences between phenotypic coefficient of variation (PCV) and genetic coefficient of variation (GCV) were significantly lower for crude protein (0.45), followed by pod length (1.45) and 100 seed weight (2.6). The result suggests that the environment had less effect on the expression of these traits. Therefore, selection based on these traits might increase soybeans performance in all locations. The findings have demonstrated the stability of traits in different locations which is a useful information in soybean breeding programs. TGX 194-1F and TGX 1908-8F were genotypes with high crude protein content, and revealed stable performance across the three environments. TGX 1987-10F, TGX 1987-20F and TGX 1910-14F had better performance compared to Bossier.

Key words: Soybeans, genotype, yield component, yield.

INTRODUCTION

Soybean (*Glycine max* (L) Merrill) is a legume produced worldwide, and its production has increased from 17 million metric tonnes in 1960 to 230 million metric tonnes in 2008 (Hartman et al., 2011).

*Corresponding author. E-mail: domlib@yahoo.co.uk.

Soybeans cultivation has been increasing every year due to population demand, it is estimated that 6% of world's arable land is under soybean production (Aditya et al., 2011). The crop enjoys global acceptability because it grows well in a wider range of agro-ecological zones ranging from tropical and subtropical to temperate climate (Malik et al., 2007).

Apart from ecological adaptability, soybean is of choice by many farmers due to its high nutritional qualities including protein 35%, oil 19%, carbohydrate 35%, minerals 5% and vitamins (Bueno et al., 2013, Dixit et al., 2011, Popovic et al., 2013). The demand for cheap oil and protein is increasing annually to match the growing world population (Hartman et al., 2011). These nutritional values from soybeans are important to human being especially to resource-poor families, who cannot afford expensive sources of protein from meat, fish, and eggs (Aditya et al., 2011, Taira, 1990).

In addition, the soybean hull contains approximately 65% dietary fibre and offers a good source of fibre when used in various food applications (Shogren *et al.*, 1981). Soybean is also environmentally friendly in a sense that it serves in soil conservation by reducing soil erosion. Not only that but also whether under monoculture or intercropped, Soybean plays a central role replenishing soil fertility due to its legume bacterial symbiotic relationship (Bekele and Alemahu, 2011; Di Mauro et al., 2014; Gibson, 2015; Singh and Shivakumar, 2010).

In Tanzania, soybean is grown by smallholder farmers, and production varies between regions (Malema, 2005). High production has been recorded in Southern highland regions of Mbeya, Iringa and Ruvuma with an average of 900,000 kg per year (Wilson, 2015), whereas the lowest annual production (230,000 kg) have been reported in Eastern zone regions of Dar-es-salaam, Coast, Tanga, and Morogoro. Global soybean production in 2015/16 is currently forecast at 314 million tonnes (Hallam et al., 2013).

In Tanzania, soybean production is still far below the world average (Malema, 2005). The low production in Tanzania can partly be due to low yielding genotype and unfavourable environmental factors particularly erratic rains and diseases. In the eastern agro-ecological zones, the loss of genetic diversity like *3H/1* and *Bossier* soybean varieties which were previously adapted (Malema, 2005) and the outbreak of the disease (Oerke, 2006, Tukamuhabwa et al., 2012) could be an important constraint to soybean production in the region.

Breeding for new high yielding soybean genotypes that can withstand harsh climate, diseases resistant across wide agro-ecological zones of Tanzania has been a priority research agenda over years. Development of new genotypes has involved the introduction of proven high yield varieties from other research centres around the world. Alternatively breeding for preferred traits using locally available genetic resources has been an ongoing process. Recently in Tanzania, the agricultural research institute (ARI) Ilonga has introduced new soybean varieties from IITA research centre based in Malawi.

Together with these, the breeding program at the station has developed three soybean lines which are in different stages of evaluation before they can be declared new varieties.

It is one of the procedure that both newly developed and introduced genotypes have to be evaluated for their agronomic performance against the existing local check before they can be considered new varieties for commercial production or further improvement. The two varieties from IITA and the three soybean lines from Ilonga have never been evaluated.

The objective of this study, therefore, was to evaluate the new soybean genotypes for their agronomic performance.The study specifically aimed at determining the differences between genotypes in terms of their yield and yield components. Secondly, the study estimated the genetic parameters based on eleven characters of soybean genotypes. Lastly, for each genotype, the study established the relationships between yield and yield components. Results from this study are important as a basis for a successful future breeding program and increasing soybean yield in the country.

MATERIALS AND METHOD

Location and experimental design

Three locations within eastern agro-ecological zones were used as experimental sites. The names of the locations are Ilonga (06°.7S 37°38 E, 506 m.a.s.l), Mlingano (05°9 S 38^0 54 E, 183 m.a.s.l), and Kibaha (06°46 S 30°55E, 162 m.a.s.l). The research was implemented during 2013 growing season from March to July. Average rainfall, maximum, minimum and mean temperature is presented in Table 1.

Six genotypes (Table 2) were evaluated for grain yield in three growing environments varying mainly in their monthly rainfall averages (Table 1). A variety called Bossier, a released was used as a local check as it has been grown in eastern agro-ecological zone since 1978 (Malema, 2005).

The experiment was laid out in a randomised complete bock design with three replications in each location. The plot size was 2.5 m x 2 m while the spacing used was 50 cm x 10 cm between and within the rows respectively. Each treatment was sown in five rows per plot. Data were collected from the net area of 1.5 m x1.8 m of each plot excluding two border rows. The harvested net plot area was 2.7 m^2.

All agricultural practices recommended for soybeans production were applied during the course of experimentation in all 3 locations. Before maturity, all the agronomical yield components traits (days to 50% flowering, days to 95% maturity, plant height, number of pods per plant, number of seeds per plant) were recorded and at maturity, ten plants were randomly collected from each sub-plot to measure quantitative traits for example, seed weight per plant (g). Seed yield (t ha^{-1}) was calculated based on the plot area.

Data analysis

STATISTICA version 10 was used to compute Analysis of variance (ANOVA) for bean yield, yield components, and crude protein

Table 1. Monthly meteorological data of the test locations during the 2013 growing season.

Location	Variable		Month				
			March	April	May	June	July
Mlingano	RF	-	111.90	137.20	123.40	23.50	25.50
	Temp	Max	33.20	31.50	29.80	28.90	29.30
	-	Min	24.30	23.90	22.40	20.80	20.30
	-	Mean	28.80	27.70	26.10	24.90	24.80
Ilonga	RF		292.10	132.50	117.70	1.00	9.00
	Temp	Max	32.40	30.60	29.20	28.20	28.50
	-	Min	22.60	21.90	20.30	16.90	16.50
	-	Mean	27.50	26.30	24.80	22.60	22.50
Kibaha	RF		282.30	140.50	36.60	3.20	1.60
	Temp	Max	33.30	31.20	29.90	29.60	29.50
	-	Min	32.30	30.40	29.60	21.10	19.80
	-	Mean	32.80	30.80	29.80	25.40	24.70

Source: National meteorological agency, Eastern zone, SUA branch; RF = Rainfall (mm), Temp = Temperature (°C), Max =Maximum temperature; Min = Minimum temperature.

Table 2. List of 6 soybean genotypes evaluated in three growing environments (Mlingano, Kibaha, and Ilonga).

Entry	Genotype	Source	Status
1	TGX 1987-10F	IITA-Malawi	Improved
2	TGX 1987-20F	IITA-Malawi	Improved
3	TGX 1954-1F	ARI- Ilonga	Line
4	TGX 1908-8F	ARI- Ilonga	Line
5	TGX 1910-14F	ARI-Ilonga	Line
6	BOSSIER (Local check)	ARI- Ilonga	Improved

content, data were subjected to ANOVA separately for each location and over combined locations. The statistical model applied for this ANOVA are:

Single location

Single location analysis was carried out as described by Gomez and Gomez (1984) for randomised complete block design (RCBD).

$$\mathbf{Y_{ij} = \mu + B_i + G_j + \varepsilon_{ij}} \quad (1)$$

Combined location analysis

$$Y_{ijk} = \mu + B_i + G_j + L_k + GL_{jk} + \boldsymbol{\varepsilon}_{ijk} \quad (2)$$

Where, Y_{ijk} = observed value of genotype j in block i of location k, μ=grand mean, B_i=block effect, G_j=effect of genotype, L_k= Location effect, GL_{jk} = the interaction effect of genotype j with location k, $\mathcal{E}_{ijk}$ = error (residual) effect of genotype j in block i of environment k. Means among each character were compared by least significant difference (LSD) test at 5% levels of significance.

The combined component of variance and correlation coefficient was calculated as described by Al-Jibouri et al. (1958). The observed mean squares obtained in the combined ANOVA was used to separate out the effects of genotype, environments, and their interaction. Path coefficient analysis (Dewey and Lu, 1959) was used to determine direct and indirect effects of days to 50% flowering, days to 95% maturity, plant height, the number of pods per plant, the number of seeds per plant, 100 seeds weight and grain yield (Figure 1).

The double arrow lines represent the correlation between variables (r_{ij}), while the single arrow lines indicate the direct effects of yield component to the soybean yield as measured by path coeffiecint (P_{ij}) (Figure 1). The path coefficient in the present study was calculated based on following equestions:

r17=P17+r12P27+r13P37+r14P47+r15P57+r16P67
r27=r12P17+P27+r23P37+r24P47+r25P57+r26P67
r37=r13P17+r23P27+P37+r34P47+r35P57+r36P67
r47=r14P17+r24P27+r34P37+P47+r45P57+r46P67
r57=r15P17+r25P27+r35P37+r45P47+P57+r56P67
r67=r16P17+r26P27+r36P37+r46P47+r56P57+P67

The residual factor (PX7) was computed as follows:

1=P2X5+P217+P227+P237+P247+P257+P267+2P17r12P27+2P17r13P37+2P17r14P47+2P17+r15P57+2P17r16P67+2P27r23P37+2P27r24P47+2P27r25P57+2P27r26P67+2P37r34P47+2P37r35P57+2P37r36P67+2P47r45P57+2P47r46P67+2P57r56P67

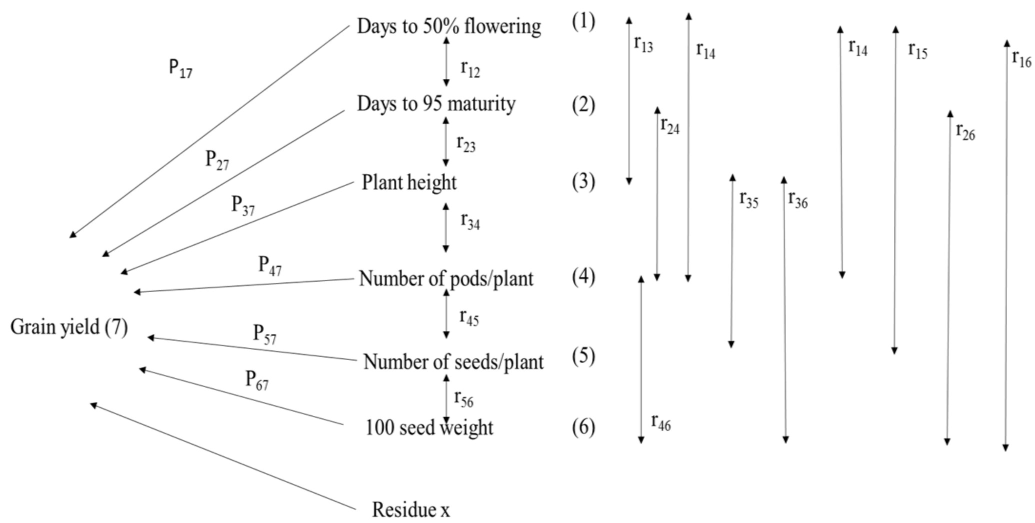

Figure.1 Path coefficient analysis of 7 yield components: double arrow lines represent the correlation between variables (rij), while the single arrow lines indicate the direct effects of yield component to the soybean yield as measured by path coefficient (Pij).

In the path model:

Rij = simple correlation coefficients for measuring the mutual association of two variables
Pij = path coefficient for measuring direct influence between variables to yield
RijPij = indirect effects of variables upon another through the other variable
Px = the residue effect in the path analysis model computed as 1-P2X7 i and j = (1, 2, 3…,7).

RESULT AND DISCUSSION

Effects of genotypes

The result in Table 3 show that the effects of genotypes on yield and yield component was significant ($P < 0.05$) confirming the previous studies (De Bruin and Pedersen, 2009; Liu et al., 2005; Norsworthy and Shipe, 2005).

In this study, the genotypes TGX 1954-1F and TGX 1908-8F outperformed the local check in all the three locations with the average mean performance of 611.69 and 609.93 kg/ha respectively, while Bossier had the lowest (260.46kg/ha) yield in all locations. Alongside TGX 1987-10F, TGX 1987-20F and TGX 1910-14F yield performance were significantly high than the control (Bossier) in all locations. The low yielding ability of Bossier variety was previously reported by Bonato et al. (2006). The mean performance of the genotypes across the location revealed that TGX 1908-8F had the highest number of seed per plant (66.11), followed by TGX1954-1F (52.00) and Bossier showed the lowest (41.22). TGX1954-1F and TGX 1908-8F had the largest number of pods per plant with 58.11and 53.11 respectively, and Bossier revealed the least value (31.66).

Similarly, the genotype TGX1954-1F and TGX 1908-8F had the highest plant height with 34 and 33cm respectively while Bossier recorded the least (27.05cm). High yields attained by TGX 1954-1F and TGX 1908-8F genotypes could be explained by the high performance of agronomic variables such as the number of pods per plant and number of seeds per plant which featured high in these genotypes compared to others (Table 3).

Effects of environment

The agronomic yield performance and yield across the 3 locations are presented in Table 4. It was established from this study that, yield and yield components varied significantly ($P < 0.05$) with location. The mean yield was significantly high at Ilonga (728kg/ha) and the lowest was recorded at Kibaha. High yield at Ilonga could be attributed to relatively adequate rainfall during the growing month of March and 2°C lower average temperatures which mimics closer to the highland agro-ecosystem where there is a cooler environment suitable for soybeans as also reported by other authors (Liu et al., 2008; Ragsdale et al., 2011). Number of pods per plant, pod length, number of seed per plant, plant height and 100 seed weight were significantly high at Ilonga compared to other sites. These agronomic performance attributed to high yield performances recorded at Ilonga site (Table 4). The seed yield performance across the three locations showed that the performance of all genotypes are consistent under varying agro-ecological zones.

However, moderate yield performances to all genotypes recorded at Kibaha might be due to low precipitation (36.6mm) during critical period of pod set.

Table 3. Effect of genotype on yield and yield components.

Genotype	50% flowering (days)	95% maturity (days)	Plant height (cm)	No. of pods/plant	Pod length (cm)	No. of seeds/plant	100 seeds (g)	Yield (kg/h)	Crude protein (%)
TGX 1987-10F	40.55[d]	73.88[d]	33.58[a]	40.68[b]	3.21[b]	53.44[b]	12.15[de]	496.99[bc]	40.26[b]
TGX 1987-20F	41.88[c]	73.33[e]	28.72[b]	29.22[c]	3.09[b]	53.78[b]	11.21[e]	559.27[ab]	40.46[b]
TGX 1954-1F	43.11[b]	86.88[a]	34.00[a]	58.11[a]	3.13[b]	52.00[b]	13.01[cd]	611.69[a]	37.12[b]
TGX 1910-14F	37.77[f]	72.55[f]	27.00[b]	33.22[bc]	3.68[a]	61.44[a]	14.44[a]	519.68[b]	39.81[b]
TGX 1908-8F	45.33[a]	86.44[b]	33.00[a]	53.11[a]	3.18[b]	66.11[a]	13.38[bc]	609.93[a]	40.21[b]
BOSSIER	39.77[e]	54.77[c]	27.05[b]	25.89[c]	2.49[a]	30.33[c]	14.34[ab]	260.46[c]	23.65[a]
Overall mean	41.40	78.97	30.55	41.00	3.32	54.66	13.08	538.82	38.92
S.E (±)	0.26	0.25	1.32	4.75	0.09	2.96	0.62	48.05	0.15
CV	1.16	0.49	7.65	20.37	4.52	9.5	7.94	15.92	0.65

Means with the same superscript letter(s) in the same column are not statistically different.

Table 4. Effects of location on yield and yield components of soybean.

Location	50% flowering (days)	95% maturity (day)	Plant height (cm)	No. of pods/plant	Pod length (cm)	No. of seed/plant	100 seeds wt (g)	Yield (kg/ha)	Crude protein (%)
Ilonga	42.56[a]	81.56[a]	36.50[a]	49.60[a]	3.39[a]	68.80[a]	15.28[a]	728.00[a]	38.92[a]
Kibaha	41.67[b]	77.50[b]	28.53[b]	48.22[a]	3.20[b]	50.56[b]	12.14[b]	343.08[c]	38.94[a]
Mlingano	38.00[c]	77.88[b]	26.61[b]	25.17[b]	3.12[b]	44.67[c]	11.84[b]	545.76[b]	38.89[a]
Overall mean	40.74	78.95	30.55	40.99	3.24	54.67	13.08	538.95	38.92
S.E (±)	0.27	0.22	1.34	4.82	0.09	2.99	0.59	49.50	0.14
CV	1.16	0.49	7.64	20.37	4.52	9.50	7.94	15.92	0.65

Mean with the same superscript letter(s) in the same column are not statistically different following Least Square Difference comparison at 5% level.

The released variety (Bossier) had poor performance across all locations (Table 5). These genotypes showed strong stability and promising stock for future soybean breeding programmes.

Combined effects of genotype and environment

The interaction of genotype x location computed from this study is presented in Table 5. The genotype by environment interaction resulted in significant differences in yield and yield components of soybean. The combination involving the genotypes with Ilonga resulted into the higher performance of soybean in all parameters while the combination of genotype with Mlingano had the poorest performance. This implies that, all genotypes were better adapted at Ilonga than Mlingano where the control check was the poorest performer. The poor performance at Mlingano and Kibaha could be associated with their ecological condition as they are located more at lower altitude with relatively higher temperatures than Ilonga. Adaptability of soybean to high altitude location has been reported by many authors (Liu et al., 2005; Liu et al., 2008; Ragsdale et al., 2011). However, of the all the genotypes tested, TGX 1954-1F combined well with all the three locations (Table 5) implying that it can well be used as a potential variety for all the three locations.

Table 5. Combined effects of genotypes and environment on the mean square values of yield and yield components of soybean.

Source of variation	Days 50% flowering	Days 95% maturity	Plant height (cm)	No. of pods/plant	Pod length (cm)	100seed weight (g)	Yield (kg/ha)	Crude protein (%)
ILONGA*G1	41.67b	76.67b	39.00e	52.67fg	3.43b	14.32bc	774.77ef	40.18b
ILONGA*G2	43.67b	75.00b	37.33de	27.67bcd	3.27b	13.04bc	748.01ef	40.43b
ILONGA*G3	44.33b	89.67b	37.67de	73.67i	3.40b	13.92bc	897.87f	37.13b
ILONGA*G4	40.00b	75.33b	35.00cde	39.33cdef	4.27b	17.56c	663.11def	40.24b
ILONGA*G5	46.00b	88.67b	39.33e	77.00i	3.53b	15.70bc	860.93f	40.20b
ILONGA*G6	39.67b	84.00b	30.67bcde	27.33bcd	3.97b	17.15c	420.32bcd	35.35b
KIBAHA*G1	40.00b	72.00b	31.83bcde	39.67def	3.20b	11.00bc	252.60b	40.38b
KIBAHA*G2	40.00b	73.00b	26.83bcd	36.67bcde	3.00b	10.23b	385.23bcd	40.61b
KIBAHA*G3	43.00b	85.00b	33.00bcde	70.00hi	3.00b	13.27bc	421.36bcd	37.19b
KIBAHA*G4	36.33b	70.00b	22.33b	36.33bcde	3.5b	12.67bc	319.03bc	39.56b
KIBAHA*G5	46.00b	84.67b	31.00bcde	56.33gh	3.00b	13.47bc	319.35bc	40.28b
KIBAHA*G6	41.67b	80.33b	26.17bcd	50.33efg	3.5b	12.20bc	360.95bc	35.61b
MLINGANO*G1	40.00b	73.00b	29.67bcde	29.67bcd	3.00b	11.13bc	463.59bcd	40.23b
MLINGANO*G2	42.00b	72.00b	22.00b	23.33b	3.00b	10.37b	544.56cde	40.35b
MLINGANO*G3	42.00b	86.00b	31.33bcde	30.67bcd	3.00b	11.83bc	515.84bcde	37.06b
MLINGANO*G4	37.00b	72.33b	23.67bc	24.00bc	3.27b	13.10bc	576.91cde	39.62b
MLINGANO*G5	44.00b	86.00b	28.67bcde	26.00bcd	3.00b	10.97bc	649.50def	40.15b
MLINGANO*G6	0.00a	0.0000a	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a

G1= TGX 1987-10F,G2= TGX 1987-20F, G3= TGX 1954-1F, G4= TGX 1908-8F,G5= TGX 1910-14F, G6= Bossier: Mean with the same supescript letter(s) in the same column are not statistically different following Least Square Difference comparison at 5% level.

Genotypic coefficients of variation

The estimates of the genotypic coefficient of variation (GCV), the phenotypic coefficient of variation (PCV), broad sense heritability and genetic advance in percent of the mean for eleven traits of soybean are presented in Table 6. Significant differences were recorded for all agronomic traits under study. Indicating that all accessions are promising for breeding programs. The PCV and GCV estimates were significantly high for pods per plants (49.49/27.04) followed by yield (39.16/32.81), seed per plant (35.36/22.53), plant height (20.56/15.76), initial plant per plot (20.56/15.76), 100 seed weight (17.95/15.36), and pod length (11.14/9.69).

The lowest PCV/GCV estimate was revealed in crude protein (1.45/0.98). The finding also revealed that the differences between PCV and GCV were significantly lower for crude protein (0.45), followed by pod length (1.45), 100 seed weight (2.6) and 50% flowering day (3.2). Indicating that the environment had less effects on the expression of these traits, thus can be useful in soybean screening programs. (Aditya et al., 2011) also reported significant lower differences between PCV and GCV in 50% flowering and 100 seed weight.

Correlation analysis

The correlation coefficient of 7 agronomical traits are shown in Table 7. The findings revealed that all the agronomic characters studied showed strong positive correlation with grain yield except plant height and 100seed weight at Mlingano and Kibaha (Table 7).

Days to 50% flowering, number of pods per plant and number of seeds per plant showed positive and strong correlation with grain yield. Indicating that these traits are important in determining quantitative traits such yield in soybean. Several authors (Abady et al., 2013;

Table 6. Estimation of genetic parameters for eleven characters of soybean genotypes.

Characters	GCV	PCV	hb2 (%)	EGA	GAM (%)
Initial plants /plot	15.76	20.56	72.60	9.17	12.70
50% flowering (days)	2.26	5.46	17.40	1.02	2.47
95% maturity (days)	2.00	6.44	9.60	1.29	1.64
Plant height	15.76	20.56	58.78	9.73	31.91
Pods per plant	27.04	49.49	29.87	12.48	30.45
Pod length	9.69	11.14	75.81	0.74	22.29
Seeds per plant	22.53	35.36	40.60	20.72	37.90
100 seeds wt (gm)	15.36	17.95	73.30	4.54	34.72
Yield (Kg/ha)	32.81	39.16	70.18	390.91	72.55
Crude protein (%)	0.98	1.45	46.42	0.69	1.78

The genotypic coefficient of variation (GCV), the Phenotypic coefficient of variation (PCV), Broad sense heritability (hb2), Expected genetic advance (EGA) and Genetic advance as percent of the mean (GAM).

Table 7. Correlation coefficients between characters computed from six genotypes of soybean grown in different locations, the upper: value Ilonga: middle: Kibaha and lower: Mlingano.

Characters	(7)	(6)	(5)	(4)	(3)	(2)	(1)
	0.7067 * *	-0.5185 *	0.6206 * *	0.6681 * *	0.6282 * *	0.5037 *	1.000
(1) DF	0.1680	0.3179	0.3510	0.6622 * *	0.6263 * *	0.8905 * * *	1.000
	0.2466	-0.7190***	-0.3440	0.3448	0.4061	0.6018**	1.000
	0.2264	0.0129	0.1944	0.6606 * *	0.0447	-	-
(2) DM	0.4099	0.4615	0.2103	0.8033 * * *	0.5322 *	-	-
	0.2702	-0.0415	-0.1828	0.2120	0.6189**	-	-
	0.6751 * *	-0.4174	0.6958 * *	0.5818 *	-	-	-
(3) PH	-0.0187	0.1852	-0.0416	0.4278	-	-	-
	-0.0441	-0.2183	-0.1287	0.7077**	-	-	-
	0.6277 * *	-0.0758	0.7652 * * *	-	-	-	-
(4) NPP	0.2597	0.4648	-0.0875	-	-	-	-
	0.1652	0.3316	0.0508	-	-	-	-
	0.7783 * * *	-0.2889	-	-	-	-	-
(5) NSP	0.4209	-0.2038	-	-	-	-	-
	0.4349	0.2515	-	-	-	-	-
	-0.4442	-	-	-	-	-	-
(6) SW	-0.0548	-	-	-	-	-	-
	0.0539	-	-	-	-	-	-
	1.000	-	-	-	-	-	-
(7) GY	1.000	-	-	-	-	-	-
	1.000	-	-	-	-	-	-

*, **,***: Significant at P=0.05, P= 0.01 and P=0.001 probability levels, respectively DF= days to 50% flowering, DM=days to 95% maturity, PH=Plant height, NPP=Number of pods per plant, NSP=Number of seeds per plant, SW=100 seeds weight, GY= Grain yield.

Aditya et al., 2011; Malik et al., 2007; Ngalamu et al., 2013) reported similar results on the importance of the same yield components in determining grain yield in soybeans, hence selection based on these traits could improve soybean yields. 100 seed weight showed negative correlation yield, similar result was revealed by Malik et al. (2007) and Srinives and Giragulvattanaporn (1986).

Path coefficient analysis presented in Table 8 and Figure 1 showed that all the yield components studied had

Table 8. Path coefficients for soybean grain yield influencing factors at Ilonga, Kibaha, and Mlingano.

S/N	Effect	Ilonga	Kibaha	Mlingano
1	**Correlation of days to 50% flowering on with yield, r_{17}**	**0.707****	**0.168**	**0.247**
	Direct effect of days to 50% flowering, P_{17}	0.279	-1.587	0.622
	Indirect effect via days to 95% maturity, $r_{12}P_{27}$	0.001	1.549	0.194
	Indirect effect via plant height, $r_{13}P_{37}$	0.070	0.065	-0.275
	Indierct effect via number of pods per plant, $r_{14}P_{47}$	-0.021	0.031	0.162
	Indierect effect via number of seeds per plant, $r_{15}P_{57}$	0.323	0.198	-0.171
	Indierct effect via 100 seed weight, $r_{16}P_{67}$	0.055	-0.089	-0.285
	Total	**0.707**	**0.167**	**0.247**
2	**Correlation of days to 95% maturity with yield, r_{27}**	**0.226**	**0.409**	**0.270**
	Direct effect of days to 95% maturity, P_{27}	0.001	1.741	0.323
	Indirect effect via days to 50% flowering, $r_{21}P_{17}$	0.141	-1.412	0.374
	Indierct effect via plant height, $r_{23}P_{37}$	0.005	0.055	-0.419
	Indirect effect via number of pods per plant, $r_{24}P_{47}$	-0.021	0.038	0.099
	Indirect effect via number of seeds per plant, r25P57	0.101	0.116	-0.091
	Indirect effect via 100 seed weight, r26P67	-0.001	-0.129	-0.017
	Total	**0.226**	**0.409**	**0.270**
3	**Correlation of plant height with yield, r_{37}**	**0.675****	**-0.019**	**-0.044**
	Direct effect of plant height, P_{37}	0.112	0.104	-0.677
	Indirect effect via days to 50% flowering, $r_{31}P_{17}$	0.175	-0.993	0.253
	Indirect effect via days to 95% maturity, $r_{32}P_{27}$	0.000	0.926	0.199
	Indirect effect via number of pods per plant, $r_{34}P_{47}$	-0.018	0.020	0.331
	Indirect effect via number of seeds per plant, $r_{35}P_{57}$	0.362	-0.024	-0.064
	Indirect effect via 100 seed weight, $r_{36}P_{67}$	0.044	-0.052	-0.087
	Total	**0.675**	**-0.019**	**-0.045**
4	**Correlation of number of pods per plant with yield, r_{47}**	**0.627****	**0.260**	**0.165**
	Direct effect of number of pods per plant, P_{47}	-0.031	0.047	0.468
	Indirect effect via days to 50% flowering, $r_{41}P_{17}$	0.186	-1.051	0.215
	Indirect effect via days to 95% maturity, $r_{42}P_{27}$	0.001	1.398	0.068
	Indirect effect via plant height, $r_{43}P_{37}$	0.065	0.045	-0.479
	Indirect effect via number of seeds per plant, $r_{45}P_{57}$	0.398	-0.049	0.025
	Indirect effect via 100 seed weight, $r_{46}P_{67}$	0.008	-0.130	-0.132
	Total	**0.627**	**0.260**	**0.165**
5	**Correlation of number of seeds/plant with yield, r_{57}**	**0.778*****	**0.421**	**0.435**
	Direct effect of number of seeds per plant, P_{57}	0.520	0.563	0.497
	Indirect effect via days to 50% flowering, $r_{51}P_{17}$	0.173	-0.557	-0.214
	Indirect effect via days to 95% maturity, $r_{52}P_{27}$	0.000	0.366	-0.059
	Indirect effect via plant height, $r_{53}P_{37}$	0.079	-0.004	0.086
	Indirect effect via number of pods per plant, $r_{54}P_{47}$	-0.024	-0.004	0.025
	Indirect effect via 100 seed weight, $r_{56}P_{67}$	0.030	0.057	0.100
	Total	**0.778**	**0.421**	**0.435**
6	**Correlation of 100 seed weight with yield, r_{67}**	**-0.444**	**-0.055**	**-0.054**
	Direct effect of 100 seed weight, P_{67}	-0.105	-0.280	0.397
	Indirect effect via days to 50% flowering, $r_{61}P_{17}$	-0.145	-0.505	-0.447
	Indirect effect via days to 95% maturity, $r_{62}P_{27}$	0.000	0.804	-0.014
	Indirect effect via plant height, $r_{63}P_{37}$	-0.047	0.019	0.148
	Indirect effect via number of pods per plant, $r_{64}P_{47}$	0.002	0.022	-0.155
	Indirect effect via number of seeds per plant, $r_{65}P_{57}$	-0.150	-0.115	0.125
	Total	**0.445**	**-0.055**	**0.054**

positive direct effects on yield in all locations except 100 seed weight which had negative direct effects on yield in all locations. Similar results were also reported by (Sharma et al., 1983).

However, these are contrary to the result of Malik et al. (2007) and Srinives and Giragulvattanaporn (1986) who revealed that days to maturity and days to 50% flowering had negative direct effect to yield. This inconsistency in results might be due to the effect of abiotic factors. Several reports (Arshad et al., 2006; Malik et al., 2007; Srinives and Giragulvattanaporn, 1986) documented that correlation coefficient for seed yield revealed a significant association with plant height.

Contrary to the findings of this study, plant height showed positive direct effect on yield at Ilonga (r=0.675), while at Kibaha and Mlingano revealed negative direct effect on yield (r= -0.019 and -0.044) respectively. This inconsistancy might be due to significant low plant height recorded at Kibaha (28.5) and Mlingano (26.61) (Table 4) which might also affected the seed yield performance. The reasons for low yield performance of genotypes at Kibaha and Mlingano could also be attributed to low precipation recoreded during the study period (Table 8).

Based on the present findings, days to 50% flowering, days to 95% maturity, plant height, number of pods per plant, and number of seed per plant showed a positive and significant correlation across the locations studied. These traits suggested being effective selection criterion in soybean improvement programmes.

Conclusion

The results from the present study therefore conclude that genotype and location interaction had a high positive correlation with all agronomic yield expect 100 seed weight. The LSD mean separation picked all genotypes as the high adaptable and good yielder across the all three locations as compared to the check.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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