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RESEARCH ARTICLE

Yield Advantage of Elite Cereal and Legume Genotypes in Varying Potential Agro-ecologies of Central Tanzania

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ABSTRACT

Ten elite genotypes in total (of groundnut, pigeon pea, sorghum and pearl millet) and four local checks (one for each crop) were used in the study to identify legume and cereal genotypes of higher productivity in the varying potential agro-ecologies. The experiments were established following an incomplete randomized block design with two farmers selected per sub agro-ecology as replications. Combined analysis of variance over locations was carried out for grain yield and yield components. The results showed significant differences ($P \leq 0.05$) among groundnut and pearl millet genotypes tested for grain yield while for pigeon pea and sorghum genotypes the differences were insignificant ($P \leq 0.05$). Genotype ICGV-SM 05650 of groundnut had the highest grain yield of 2105.08 kg ha^{-1}, whereas the lowest grain yield of 1538.87 kg ha^{-1} was recorded in ICGV-SM 02724 in the high potential agro-ecology. Pearl millet genotype IP 8774 ranked highest in terms of yield performance (1049.4 kg ha^{-1}) and the local check had the lowest yield of 388.9 kg ha^{-1}. Though non-significant differences ($P \leq 0.05$) among genotypes tested for grain yield were observed in pigeon pea and sorghum genotypes however, pigeon pea genotype ICEAP 00040 had a slightly higher grain yield of 779.17 kg ha^{-1} and sorghum genotype GAMBELLA 1107 outperformed the other genotypes with grain yield of 1420.8 kg ha^{-1}. Genotypes ICGV-SM 05650, ICEAP 00040, GAMBELLA 1107 and IP8774 were therefore recommended for deployment in these varying potential agro-ecologies due to their superior performance in terms of grain yield.

Keywords: Legumes and cereal genotypes, productivity, grain yield

INTRODUCTION

Small holder farmers in the semi-arid areas of the tropics widely grow legume and cereal grains for a number of benefits such as nutritious food, soil fertility and household income (Mihale et al., 2009; Shiferaw et al., 2008). The legumes whose edible parts are the grains include cowpea, pigeon pea, chickpea, groundnut, common bean, soybean and faba bean (Singh et al., 2007). In the developing countries, they play an important role in sustainable agricultural production, food security, nutrition and income systems. Nevertheless, their production in the developing countries is still being constrained by a number of biotic (pests and diseases), abiotic (drought, frost, heat and salinity), edaphic (soil nutrient deficits) and policy issues (cereals are given more priority compared to legumes) (Ojiewo et al., 2019). On the other hand, cereal grains include; wheat, maize, rice, millet, sorghum, barley and rye. These are grown in larger quantities and offer more food energy than other types of crops worldwide (Sarwar et al., 2013). In spite of this, cereals benefit from the legumes in these intercropping systems as they utilize atmospheric nitrogen fixed in symbiotic association with the rhizobia. Crews and Peoples (2005) observed that legumes fix soil nitrogen which improves soil health status, thus increasing farm productivity due to reduction in production cost incurred through exogenous application of inorganic fertilizers leading to higher farm productivity.

Drought resistant cereal crops such as sorghum (Sorghum bicolor), pearl millet (Pennisetum glaucum) and legumes like groundnut (Arachis hypogaea), pigeon pea (Cajanus cajan) and chickpea (Cicer arietinum) were observed by Serraj et al. (2003) to be grown in the semi-arid tropics particularly in the semi-arid regions of central Tanzania since they have a relative ability to tolerate periods of drought and still yield grain and biomass. However, low crop productivity of less than fifty per cent of the expected grain yields for legumes (pigeon pea, pea nut and Bambara nuts) and cereals (maize, sorghum and pearl millet) in the farming areas of Kongwa and Kiteto districts in the central zone of Tanzania were cited by Okori (2014). Consequently, the Africa RISING team has developed new highly productive and resistant varieties of legumes and cereals which when supported with fitting scaling models will provide farmers with new alternatives for production and are thought to increase productivity by 2-3 times thus enhancing options for land management, nutrition and income for smallholder farmers (Okori et al., 2017).

Research studies on the newly developed elite legumes and cereal genotypes are still being implemented in these three sub agro-ecologies of central Tanzania classified based on the amount of precipitation received annually i.e. high potential zone which receives more than 500mm of rainfall; moderate potential zone receives between 400-500mm of rainfall and low potential zone receives less than 350mm of rainfall (Hoeschle-Zeledon, 2019). These newly adapted genotypes of groundnut, pigeon pea, sorghum and pearl millet are targeted in these sub agro-ecologies to increase productivity, income, nutrition, food security as well as improve soil health (Okori et al., 2017). Therefore, this study aims at identifying legume and cereal genotypes of higher productivity in these varying potential agro-ecologies.

MATERIALS AND METHODS

Experimental sites and Materials used for the study

The experiments were conducted during the 2019-2020 cropping season in three sub agro-ecologies of Central zone of Tanzania (Table 1). A total of ten elite genotypes (groundnut, pigeon pea, sorghum and pearl millet) obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT-MALAWI) and four local checks from the local market in Dodoma as presented in Table 2 were used in the study.

Table 1. Characteristics of the experimental sites

	Locations					
	Kongwa		Kiteto		Kongwa	
	Manyusi	Mlali	Njoro 1	Njoro 2	Laikala	Moleti
Altitude (masl)	900-1000		500-1200		900-1000	
Latitude	5° 30' to 6° 00' S		05°52'00''S		5° 30' to 6° 00' S	
Longitude	36°15' to 36°00' E		36°51'00''E		36°15' to 36°00' E	
Soil type	Sand loamy	Sand Clay Loamy	Sand Clay Loamy	Sand loamy	Sand loamy	Sand Clay Loamy

pH (water)	6.17	6.20	6.33	6.30	6.30	5.87
N (%)	0.08	0.05	0.05	0.05	0.05	0.04
OM (%)	0.72	0.50	0.54	0.32	0.32	0.51
P (mg/kg soil)	7.16	5.38	6.39	5.16	5.16	4.69
K(cmol(+) /kg soil)	0.76	0.86	0.80	0.51	0.51	0.66
Mg cmol(+) /kg soil	1.06	1.46	1.09	0.36	0.36	1.05
Ca cmol(+) /kg soil	3.47	1.90	3.87	1.17	1.17	2.20
EC mS/cm	0.12	0.08	0.08	0.06	0.06	0.09
CEC cmol(+) /kg soil	8.20	6.32	8.72	3.08	3.08	7.25
Mean annual rainfall	≥500mm		400-500mm		≤ 350mm	
Agro-ecological Zone	High potential		Moderate potential		Low potential	

Table 2. Description of test materials used in the study

	Crop	Genotype	Maturity duration (days)	Source
1.	Groundnut	ICGV-SM 02724	Medium (120)	ICRISAT-MALAWI
		ICGV-SM 05650	Short (90)	ICRISAT-MALAWI
		LOCAL CHECK (Mnanje)	Short (110)	DODOMA MARKET
2.	Pigeon pea	ICEAP 00554	Medium (150-180)	ICRISAT-MALAWI
		ICEAP 00557	Medium (150-180)	ICRISAT-MALAWI
		CHECK- ICEAP 00040 (Mali)	Long (190-240)	ICRISAT-MALAWI
3.	Sorghum	GAMBELLA 1107	Short (70)	ICRISAT-MALAWI
		IESV 92028 DL	Medium (90)	ICRISAT-MALAWI
		IESV 23010 DL	Medium (90)	ICRISAT-MALAWI
		LOCAL CHECK (Lugugu)	Long (110)	DODOMA MARKET
4.	Pearl millet	IP 8774	Short (70)	ICRISAT-MALAWI
		SDMV 96053	Medium (90)	ICRISAT-MALAWI
		SDMV 94005	Medium (90)	ICRISAT-MALAWI
		LOCAL CHECK (Uwele)	Long (110)	DODOMA MARKET

Methodology and experimental design

The experiments at these sites were established following an incomplete randomized block design with two farmers selected per sub agro-ecology as replications. One experiment was laid down in each village in the high potential (Manyusi and Mali); moderate potential (Njoro-1 and Njoro-2) and low potential (Laikala and Moleti) sub ecologies to test the effect of one sub agro-ecological condition in Kongwa and Kiteto districts. A total of 4 crops (sorghum, pearl millet, groundnut and pigeon pea) with test varieties were evaluated against the local landraces. The groundnut experiments were conducted in all the sub ecologies, pigeon pea in the high and moderate, sorghum in the high and low and pearl millet occurred only in the low potential agro-ecology. The plot size was 7 rows, 8 m long spaced at 75 cm between ridges.

Data collection

Collected data included days to 50% flowering and grain yield (assessed based on the whole plot); plant height (cm), pod weight (collected from ten plants per plot); 100 grain weight (obtained by counting 100 seeds at random from each net plot and their weight was recorded); Disease severity for leaf spots was scored based on a 1-9 severity scale according to Subrahmanyam et al. (1995). Disease score 1 means 0% foliar infection; 2 for 1–5%; 3 for 6–10%; 4 for 11–20%, 5 for 21–30%; 6 for 31–40%; 7 for 41–60%, 8 for 61–80% and 9 for 81–100% of foliar area infection with plants having almost all leaves defoliated leaving bare stems. Percentage severity of leaves infected by leaf spots per plant was recorded on five middle plants at 90 days after sowing from each plot and averaged for each genotype. Insect pest damage for aphids was scored based on a 0 to 5 rating scale by Souleymane et al. (2013) as follows: 0 = no aphids, 1= a few individual aphids, 2 = few small individual colonies, 3 = several small colonies, 4 = large individual colonies, 5 = large continuous colonies). Scoring was done on five plants from each plot at 90 days after sowing and average score recorded for each genotype.

Statistical analysis

Yield and yield components data were subjected to analysis of variance (ANOVA) using GenStat 16th Edition and mean separation was done using Tukey's and LSD tests at 5% probability level.

RESULTS

Performance of crop genotypes in different potential agro-ecologies in Kongwa and Kiteto districts

Groundnut

Performance results across the varying potential agro-ecologies (Table 3) showed significant differences ($P \leq 0.05$) among the genotypes tested for grain yield, days to 50% flowering, 100 seed weight, leaf spot severity and aphids damage while pod weight and number of pods per plant were insignificant. Even though genotypic differences were not significant at high and moderate potential agro-ecologies, genotype ICGV-SM 05650 had the highest grain yields of 2105.08 kg ha^{-1}, 1014.07 kg ha^{-1} and 1487.08 kg ha^{-1} respectively in all the ecologies, while the lowest grain yields (1538.87 kg ha^{-1}, 506.19 kg ha^{-1} and 670.67 kg ha^{-1}) respectively were recorded in ICGV-SM 02724. The high potential agro-ecology generally had the best grain yield performance in all the genotypes tested compared to the other sub agro-ecologies.

Table 3. Performance of elite groundnut genotypes in the varying potential agro-ecologies in Kongwa and Kiteto districts

Treatments	Days to 50% Flowering	Leaf spot severity	Aphid damage	No. of pods/ plant	Pod weight/ plot (kg)	100 Seed weight (g)	Grain yield (kg/ha)
High							
ICGV-SM 02724	40.50 ^{de}	2.250 ^{a}	2.000 ^{b}	41.15	3.86	50.15 ^{cd}	1538.87 ^{ab}
ICGV-SM 05650	31.25 ^{a}	3.500 ^{abc}	1.250^{a}	30.40	5.22	50.53 ^{d}	2105.08 ^{b}
Local Check	34.75 ^{abc}	4.750 ^{c}	2.500^{bc}	38.90	4.60	36.88 ^{abc}	1950.67 ^{b}
Moderate							
ICGV-SM 02724	43.50 ^{e}	2.250 ^{a}	2.000^{b}	38.20	2.37	52.70 ^{d}	506.19 ^{a}
ICGV-SM 05650	38.50 ^{cde}	2.750 ^{ab}	1.000^{a}	36.25	3.55	39.70 ^{abcd}	1014.07 ^{ab}
Local Check	42.00 ^{de}	4.000 ^{bc}	3.000^{c}	31.35	2.25	36.85 ^{abc}	648.55 ^{a}
Low							
ICGV-SM 02724	43.50 ^{e}	2.500 ^{a}	2.000^{b}	30.15	2.64	46.58 ^{bcd}	670.67 ^{a}
ICGV-SM 05650	32.50 ^{ab}	2.500 ^{a}	1.000^{a}	30.80	4.09	36.70 ^{ab}	1487.08 ^{ab}
Local Check	37.00 ^{bcd}	4.500 ^{c}	2.250^{b}	33.80	2.35	30.03 ^{a}	673.53 ^{a}
Grand mean	38.17	3.222	1.889	34.6	3.44	42.23	1177.19
SE±	0.634	0.1623	0.0895	3.34	0.412	1.623	154.001
P-value	0.001	0.001	0.001	0.699	0.057	0.001	0.022
LSD $_{(P=0.05)}$	1.843	0.4719	0.2602	ns	ns	4.717	447.675
CV (%)	5.8	17.5	16.4	33.5	41.5	13.3	45.3

Means with the different letter(s) in the same column for each sub ecology are significantly different ($P \leq 0.05$) following separation by Tukey's Test. CV = Coefficient of variation, S.E± = Standard error, LSD (Least significant difference), ns (Not significant). Mean separation test values also indicated.

The relationship between sub ecology and grain yield of groundnut genotypes (Figure 1) showed that ICGV-SM 05650 recorded the highest grain yield followed by the Local (Mnanje) and ICGV-SM 02724.

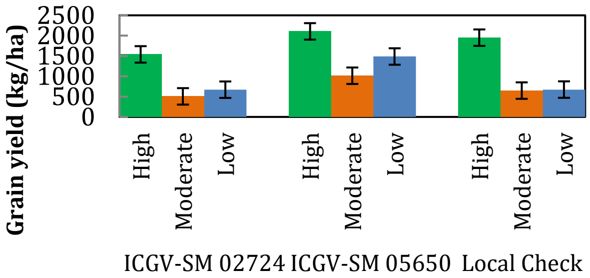

Figure 1. Yield performance of groundnut genotypes in different potential agro-ecologies in Kongwa and Kiteto districts

Pigeon pea

Performance results across the varying potential agro-ecologies (Table 4) showed significant differences (P ≤ 0.05) among the genotypes tested for days to 50% flowering, plant height, leaf spot severity and 100 seed weight while pod weight and grain yield were non-significant. Even though genotypic differences in grain yield were insignificant, genotype ICEAP 00040-Local had the highest grain yields of 779.17 kg ha^{-1} and 673.73 kg ha^{-1} at high and moderate potential agro-ecologies respectively compared to the others.

Table 4. Performance of elite pigeon pea genotypes in the varying potential agro-ecologies in Kongwa and Kiteto districts

Treatments	Days to 50% Flowering	Plant height (cm)	Leaf spot severity	Pod weight/ plot (kg)	100 Seed weight (g)	Grain yield (kg/ha)
High						
ICEAP 00554	75.00 ^{a}	127.0 ^{ab}	0.50 ^{a}	3.25	24.8 ^{b}	687.50
ICEAP 00557	78.50 ^{a}	125.9 ^{ab}	0.50 ^{a}	3.64	18.8 ^{a}	770.83
ICEAP 00040-local	125.00 ^{b}	205.3 ^{c}	2.50 ^{c}	3.30	20.2 ^{ab}	779.17
Moderate						
ICEAP 00554	72.00 ^{a}	98.8 ^{ab}	0.00 ^{a}	2.10	21.8 ^{ab}	470.91
ICEAP 00557	73.25 ^{a}	89.6 ^{a}	0.75 ^{ab}	2.06	22.4 ^{ab}	233.44
ICEAP 00040-local	122.00 ^{b}	154.8 ^{b}	2.0000 ^{c}	3.212	22.40 ^{a}	673.7
Grand mean	91	133.6	1.04	2.93	21.7	602.60
SE±	2.3	8.84	0.205	0.606	0.77	130.935
P-value	<.001	<.001	<.001	0.787	0.019	0.484
LSD (0.05)	6.9	26.39	0.611	ns	2.30	ns
CV (%)	7.2	18.7	55.6	58.5	10.1	61.5

Means with the different letter(s) in the same column for each sub ecology are significantly different (P ≤ 0.05) following separation by Tukey's Test. CV = Coefficient of variation, S.E± = Standard error, LSD (Least significant difference), ns (Not significant). Mean separation test values also indicated.

The relationship between sub ecology and grain yield of pigeon pea genotypes (Figure 2) showed that generally ICEAP 00040-Local recorded the highest grain yield in both agro-ecologies compared to the other genotypes

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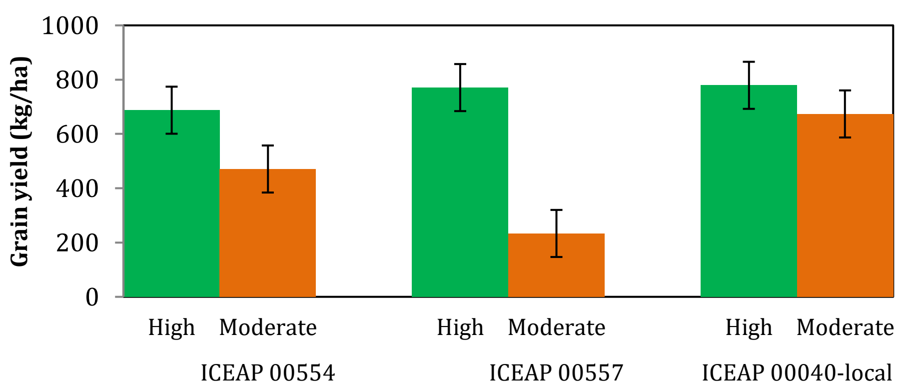

Figure 2. Yield performance of pigeon pea genotypes in different potential agro-ecologies in Kongwa and Kiteto districts

Sorghum

Performance results across the varying potential agro-ecologies (Table 5) showed significant differences (P ≤ 0.05) among the genotypes tested for days to 50% flowering, plant height, leaf spot severity, aphids damage while dry panicle weight and grain yield were insignificant. Even though genotypic differences were not significant at both high and low potential agro-ecologies, GAMBELLA 1107 had the highest grain yields of 1420.8 kg ha^{-1} and 642.0 kg ha^{-1} in these potential agro-ecologies respectively compared to the other genotypes. Lower grain yields were recorded in the Local check (Lugugu) of 562.2 kg ha^{-1} (in the high) and 429.9 kg ha^{-1} (in the low) potential agro-ecologies respectively.

Table 5. Performance of elite sorghum genotypes in the varying potential agro-ecologies in Kongwa district

Treatments	Days to 50% Flowering	Plant height (cm)	Leaf spot severity	Aphids damage	Dry panicle weight/plot (kg)	Grain yield (kg/ha)
High						
GAMBELLA 1107	67.25 ^{ab}	141.3^{ab}	2.000 ^{ab}	1.500	3.800	1420.8
IESV 92028 DL	62.00 ^{ab}	143.2^{ab}	2.000 ^{ab}	1.000	1.825	759.6
IESV 23010 DL	58.25 ^{a}	119.7^{a}	1.750 ^{a}	1.500	2.525	1038.0
LOCAL CHECK	73.50 ^{bc}	197.4^{b}	3.750 ^{c}	2.250	3.875	562.2
Low						
GAMBELLA 1107	73.75 ^{bc}	127.7 ^{a}	2.250 ^{ab}	1.000 ^{a}	1.862	642.0
IESV 92028 DL	75.50 ^{bc}	125.4^{a}	1.500 ^{a}	1.750 ^{a}	1.000	327.2
IESV 23010 DL	73.75 ^{bc}	120.6^{a}	2.000 ^{ab}	1.250 ^{a}	1.637	527.4
LOCAL CHECK	85.75 ^{c}	143.7^{ab}	3.250 ^{bc}	3.750 ^{b}	1.550	429.9
Grand mean	71.2	139.9	2.31	1.750	2.26	713
SE±	2.16	9.44	0.220	0.1950	0.550	190.6
P-value	0.001	0.007	0.001	0.005	0.265	0.201
LSD (0.05)	6.33	27.62	0.643	0.8070	ns	ns
CV (%)	8.6	19.1	26.9	31.5	68.8	75.6

Means with the different letter(s) in the same column for each sub ecology are significantly different (P ≤ 0.05) following separation by Tukey's Test. CV = Coefficient of variation, S.E± = Standard error, LSD (Least significant difference), ns (Not significant). Mean separation test values also indicated.

The relationship between sub ecology and grain yield of sorghum genotypes (Figure 3) showed that GAMBELLA 1107 recorded the highest grain yield in both agro-ecologies compared to the Local (Lugugu) with the lowest.

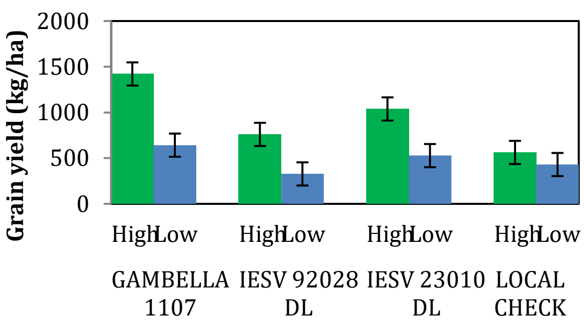

Figure 3. Yield performance of sorghum genotypes in different potential agro-ecologies in Kongwa district

Pearl millet

Performance results of the four genotypes (IP 8774, SDMV 94005, SDMV 96053 and Local check) in the low potential agro-ecology showed significant differences (P ≤ 0.05) among the genotypes tested for grain yield, days to 50% flowering, plant height and leaf spot severity while dry panicle weight was non-significant (Table 6). Genotype IP 8774 was the highest in grain yield (1049.4 kg ha^{-1}) and was significantly superior (P ≤ 0.05) to the local check (Uwele) that was lowest in yield (388.9 kg ha^{-1}).

Table 6. Performance of elite pearl millet genotypes in the low potential agro-ecology in Kongwa district

Treatments	Days to 50% Flowering	Plant height (cm)	Leaf spot severity	Dry panicle weight (kg)	Grain yield (kg/ha)

IP 8774	54.25 [a]	116.7[a]	2.250 [ab]	2.413	1049.4 [b]
SDMV 96053	54.50 [a]	113.0 [a]	2.500 [ab]	1.662	813.6 [ab]
SDMV 94005	58.00 [a]	99.3 [a]	1.500 [a]	1.725	824.7 [ab]
Local Check	77.25 [b]	188.1 [b]	3.500 [b]	3.013	388.9 [a]
Grand mean	61.0	129.3	2.44	2.20	769.14
SE±	3.18	4.59	0.324	0.483	102.167
P-value	0.004	0.001	0.020	0.245	0.015
LSD (0.05)	10.65	15.34	1.083	ns	341.654
CV (%)	10.4	7.1	26.6	43.9	26.6

Means with the different letter(s) in the same column for each sub ecology are significantly different (P ≤ 0.05) following separation by Tukey's Test. CV = Coefficient of variation, S. E± = Standard error, LSD (Least significant difference), ns (Not significant). Mean separation test values also indicated.

The relationship between sub ecology and grain yield of pearl millet genotypes (Figure 4) indicated that IP 8774 recorded the highest grain yield, followed by SDMV 94005 and SDMV 96053 while the Local (Uwele) had the lowest.

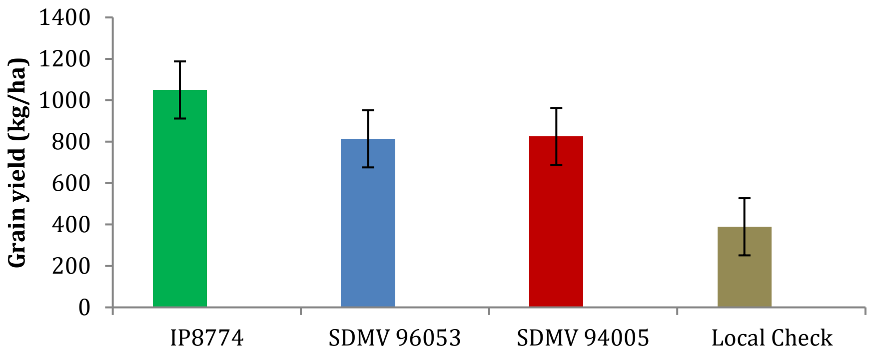

Figure 4. Yield performance of pearl millet genotypes in the low potential agro-ecology in Kongwa district

DISCUSSION

Performance of legume genotypes

The findings of the study revealed that groundnut genotypes had non-significant differences both in the high and moderate potential agro-ecologies in grain yield, but significant variations were observed in the low potential agro-ecology. ICGV-SM 05650 with the highest grain yield of 1487.08 kg ha^{-1} was superior to ICGV-SM 02724 and the Local check (Mnanje). These results show that groundnut ICGV-SM 05650 is more adapted to these potential agro-ecologies. The above findings are in agreement with the report of Hoeschle-Zeledon (2019), who reported that elite materials had superior genetics and indeed outperformed the local landraces. Kamut et al. (2013) reported that existence of genetic variability among genotypes for grain yield raises the possibilities of identifying high yielding genotypes under varying environments which is in conformity with this study.

On the other hand, pigeon pea showed non-significant differences (P ≤ 0.05) among the genotypes tested yet ICEAP 00040 (local) had the highest grain yield of 779.17 kg ha^{-1} compared to genotypes ICEAP 00557 and ICEAP 00554 with relatively lower yields of 770.83 kg ha^{-1} and 687.50 kg ha^{-1} respectively. The findings agree with the report of Okori (2014) and Hoeschle-Zeledon (2019), who observed non-significant reaction of the pigeon pea genotypes in relation to stress due to the fact that the three materials were all improved genotypes.

Performance of cereal genotypes

Performance results in the sorghum genotypes though showed non-significant differences among the tested materials for grain yield, GAMBELLA 1107 outperformed the other genotypes in both agro-ecologies indicating that it is more adapted to these environments and therefore more drought-resistant. This trait makes it able to perform even in stressful environments e.g., in Laikala and Moleti with very low precipitation of about 350 mm of rainfall per annum. The Africa RISING team through its baseline studies further confirmed that indeed drought hardy cereals such as pearl millet and sorghum can be cultivated in these semi-arid areas (Ganga Rao et al., 2013). For the pearl millet, results showed significant differences among genotypes in terms of grain yield in the low potential agro-ecology evaluated. Elite material IP 8774 outperformed the other genotypes including the Local landrace. This shows that IP 8774 is the most adapted to these micro-environments and also drought tolerant genotype since it performs better in the test site of Kongwa district receiving little amount of rainfall (about 350 mm). These findings confirm what Hoeschle-Zeledon (2019) reported that the Africa RISING team developed varieties with high yield advantage compared to the local landraces and further observed that the extra-early maturing material IP 8774 performed better when compared to the other test materials.

CONCLUSION

The study has played an important role in identifying legume and cereal genotypes of higher productivity in the various sub ecologies of central Tanzania. Findings reveal that generally elite materials outperformed the landrace controls. The study generally recommends genotypes ICGV-SM 05650 (Groundnut), ICEAP 00040 (Pigeon pea), GAMBELLA 1107 (Sorghum) and IP8774 (Pearl millet) for deployment in these varying potential agro-ecologies due to their superior performance in terms of grain yield.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests

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