Cowpea Cultivar Mixtures for Stable and Optimal Leaf and Seed Yields in a Maize Intercropping System

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Cowpea [*Vigna unguiculata* (L.) Walp.] is an important crop in many African countries, though its use as a leafy vegetable has not received adequate research attention. Leaf and grain yields are low and unstable, especially in highly variable climates in marginal areas. A study was conducted to evaluate the impact of cowpea cultivar mixtures on leaf and seed yield and stability in a cowpea-maize (*Zea mays* L.) intercropping system. Four cowpea cultivars, and a local landrace check, were used in monoculture or in different mixture levels. When leaves were harvested, seed yield was reduced on average by 57% and 59%, on-station and on-farm, respectively, with large variation among treatments. The local landrace check had the highest leaf yields on-farm where it produced a mean of 25 g/plant/2-weekly harvesting interval. It also conveyed positive mixture effects, however, yield stability across successive harvests was lowest, indicating its capacity to react to positive environmental changes. Some mixtures of more than two cultivars maintained more leaf yield stability over time across successive leaf harvests. The highest positive relative mixture effects on leaf and seed yields of up to 100% and 193%, respectively, were obtained in two-way mixtures, indicating these may offer the best combinations for improved yields and to screen for favorable and unfavorable cultivar components.

Keywords: *Vigna unguiculata,* Africa, leafy vegetable, Tanzania, yield stability

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Dual-purpose cowpea [*Vigna unguiculata* (L.) Walp.] for successive vegetable leaf and seed harvests is traditionally grown intercropped with maize in most areas of Tanzania and eastern Africa. Leaves, immature pods, and immature and mature seed of cowpea, are consumed as vegetables (Quin, 1997; Kitch et al., 1998; Karikari and Molatakgosi, 1999; Lenné et al., 2003; Mamiro et al., 2011). Processed cowpea leaves contain two-thirds the protein, 2 to 7 times the calcium, 3 to 17 times the iron, half the phosphorus, 8 times the riboflavin, 5 times the niacin and several hundred times the ascorbic acid and ß-carotene of cooked seed (Bittenbender, 1990; Mamiro et al., 2011).

Seed yield of cowpea, especially in marginal areas, remains low; no single variety has been developed with broad suitability to diverse agro-ecological conditions. Many evaluation trials have been conducted to develop cowpea varieties that would produce high seed yield despite various environmental stresses; results indicate that varieties usually lack wide adaptation to different climates and soils (Padi, 2004). When a mixture of different varieties is grown, farmers can diversify timing of germination, flowering, growth, seed-filling, and harvest (Jiggins, 1990). Cultivar mixtures vary for many characters, do not cause major changes to the agricultural system, generally increase yield stability and reduce pest infestation (Wolfe, 1985; Castro, 2001). In variable environments, mixtures with relevant heterogeneity can provide reliable and high yields through compensation and complementation. Compensatory effects occur when a weak, and a strong partner, are combined. These effects are due to a common biological phenomenon in response to fluctuating environmental conditions; these may lead to some genotypes increasing biomass, while others decrease; the contributions of individuals to total yield vary. Complementation is a result of niche partitioning, and more complete resource use results in a greater total yield of mixtures than the sum of the parts. The major advantage of mixtures is stability, which is partly contributed to by beneficial effects of compensation and complementation (Wolfe, 1985). Cultivar mixtures can be used to help manage and control biotic stresses by combining cultivars with differential resistance to diseases (Castro, 2001). Little information is available on buffering ability of mixtures to reduce abiotic stresses (Finckh and Wolfe, 2006). Mundt (2000) reported that mean yield in pure stands is not a good predictor of yield performance when using cultivar mixtures. A cultivar with a positive additive effect had a highly negative competitive effect with negative contribution to yield in soybean (*Glycine max* L.) mixtures (Mundt, 2000).

A requirement in formulating successful cultivar mixtures is the choice of correct component cultivars (Hackett et al., 2006). Different cultivars have different tolerance levels to environmental variability. A mixture of these cultivars with different characteristics may have more stable yields than the separate components (Finckh and Wolfe, 2006). For a mixture to produce more than its components grown in monoculture, it is necessary that components be different in their resource requirements or ability to withstand stresses (Hackett et al., 2006). Through the principle of intra-population buffering, a mixture of genetically different plants may have a greater chance of successful adaptation across a range of environments than a genetically homogeneous population (Helland and Holland, 2001).

Increasing numbers of components in a mixture beyond a certain number has an influence on yield improvement is unclear (Smithson and Lenné, 1996; Cowger and Weisz, 2008; Mengistu et al., 2010). In some crops, yield advantage due to mixture has been realized with more than two components in the mixture (Cowger and Weisz, 2008). Many studies have found complex mixtures to have more advantages for yield stability rather than on an increment (Erskine, 1977; Smithson and Lenné, 1996; Helland and Holland, 2001; Cowger and Weisz, 2008; Mengistu et al., 2010). The performance of a mixture is often evaluated by comparing its performance in yield, quality, or disease severity, to the mean of that parameter for the individual components that constitute a particular mixture (Cowger and Weisz, 2008).

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Yield stability (high yield over a range of environments) is considered to be an advantage of cultivar mixtures (Finckh and Wolfe, 2006). Smithson and Lenńe (1996) compared mixtures and their components from 35 data sets of yields and concluded that yields of mixtures almost always varied less among environments than those of individual components. For example, Helland and Holland (2001) tested two- and three-way oat (*Avena sativa* L.) mixtures and their components in 8 environments, and found that mixtures, on average, had more stable yield traits than pure-line stands.

Increased yield stability of cowpea, particularly in marginal areas where crop yields are usually low and variable, may be realized by adapting mixtures of improved dual-purpose cultivars to the production system. A local landrace may also be improved by mixing with advanced lines. The objective of this study was to evaluate the impact of cultivar mixtures to optimize and stabilize leaf and seed yield of dual-purpose cowpea compared with component monocultures.

Materials and Methods

Characteristics of the experimental sites

This study was conducted in Dodoma Region, central Tanzania located between 2-12° S latitudes and 30-40° E longitudes from October 2007 to March 2008. Dodoma region contains arid and semi-arid lands (USDA, 2005). The area lies at elevations from 500 to 1000 m above sea level with a mean annual rainfall of 570 mm distributed over a 3-month rainy season and a 9-month dry season. Mean minimum and maximum temperatures range between 18 and 31°C.

Two study sites were used: on-station at the Viticulture Research and Training Centre (VRTC) in Makutupora, 25 km North of Dodoma town; and on-farm at Veyula village, 3 km South of VRTC. The on-station trial field was characterized by sandy clay loam, and reddish-brown soil, while the on-farm field had a sandy clay loam, greyish to brown soil (Table 1). Both plots were fallowed the season prior to the experiment. The experiments were established on-station and on-farm in early October and early November 2007, respectively. The time difference between the two locations in establishing the experiments was set-up to reflect environmental variability in order to detect some response to seasonality.

Plant materials

Cowpea cultivars from AVRDC-The World Vegetable Center, the Agricultural Research Institute at Ilonga (Tanzania), and the International Institute of Tropical Agriculture, were selected for study: a local landrace check and 4 promising cultivars, based on a previous multi-location varietal evaluation (Tefera, 2006) (Table 2). Selection criteria included: (1) leaf and seed yield, (2) plant growth type (determinate, semi-determinate, indeterminate), to enhance heterogeneity in mixtures; and (3) a local landrace (check), to effectively compare adaptability and potential yield advantage of new cultivars.

The five cowpea cultivars were designated A to E (Table 2) and combined in all possible mixtures. The resulting 26 combination mixtures plus the 5 component monocultures provided 31 different treatment options, of which 20 were used at both locations (Table 3) due to size of land available for trials. Emphasis was put on binary or two-way mixtures to extract information on how varieties interact with each other.

A maize-cowpea intercrop was employed to reflect local farming systems. The short duration maize variety Situka M1, developed by Selian Agricultural Research Institute, Arusha, Tanzania, was selected for the intercrop.

Experimental design and data collection

Experiments were laid out in a randomized complete block design with three replications per treatment. Each plot measured 3 m wide and 6 m long and consisted of 4 rows of maize planted at a spacing of 0.75 m between rows and 0.60 m between plants within rows. Two weeks after, 4 rows of cowpea were planted between the maize rows at a spacing of 0.15 m between plants within rows. Planting cowpea in each plot followed a cultivar mixture pattern every 0.15 m according to treatment, to allow equal distribution of components within mixtures. Four seeds of only one cowpea cultivar were placed in one hole. After emergence, plants were thinned to one per hill. Leaf, mature pod, and seed yield data were collected from all plants of the two inner cowpea rows. One inner row was subjected to leaf-harvesting while the other was not.

Harvesting cowpea leaves largely followed farmers' practices, where all young fully opened leaves were picked, and a few leaves (approx. 3 of 10) were left to support further plant development. Leaves were consecutively harvested in two-week intervals for a total of 5 and 4 harvests on-station and on-farm, respectively. Harvested leaves were oven-dried at 70°C for 48 hr to determine dry matter leaf yield (DMLY).

There were three on-station pod harvests, but only one on-farm because maturity drying occurred rapidly. After pods were harvested, seed yield per plant was assessed.

Data analysis

Collected data for all traits were subjected to analysis of variance using the statistical programme PLABSTAT (Utz, 1997). A mixed linear model was used separately across leaf harvests in each location according to Utz (1997).

To determine how each level of mixture or monoculture responded across different leaf harvests, the variance of interaction effects, which corresponds to ‘ecovalence’ was calculated according to Wricke (1962, cited by Hill et al., 1998), using PLABSTAT (Utz, 1997). An ‘environment’ was defined as the conditions during a specific leaf-harvesting interval. The variance of interaction effects characterizes mixtures and corresponding components in monoculture with stability across different harvests. A treatment with the lowest variance is considered to have the ability to maintain its yield level across harvests with low variability.

To assess how varieties interact with one another in mixture, the influence is either a negative contribution (competition) or a positive one (compensation or complementation). Estimates of relative mixture effects (RME), corresponding to differences between cultivar mixtures and the mean of corresponding component monocultures on yield traits, were calculated using contrast test (ver. 5.0, Systat Software Inc., Chicago, IL). RME were measured by percent increase or decrease of mixtures over the mean yield of components in a particular mixture.

Results

Yield performance

The DMLY of component monocultures and cultivar mixtures varied in both locations (Table 4); however, there were differential DMLY performance responses of both component monocultures and cultivar mixtures in each location. When DMLY was compared for component monocultures, the local indeterminate landrace (E) produced higher yields compared to other entries, while the indeterminate cv. UG-CP-9 (KOL42) (B) had the lowest DMLY (Table 4). The highest DMLY was from the two-way mixture (CE) where 'Dakawa', a determinate cultivar (C), was combined with the indeterminate local landrace check; while the lowest DMLY was from the combination (BC) of indeterminate line 'UG-CP-9' ('KOL42') (B) and determinate cv. Dakawa (C) (Table 4).

Cultivar influenced seed yield on-station but not on-farm (Table 4). The effect of leaf-harvesting was pronounced on seed yield, being higher in rows without leaf-harvesting compared to leaf-harvested rows (Table 4). There was a response of seed yield on leaf-harvesting by component monocultures and cultivar mixtures.

Contrasts

Mixture effects on DMLY and seed yields were either positive or negative, compared with the mean of corresponding component monocultures. However, these effects were significant only in a few mixtures (Table 5). For the on-station trial, mixture BC produced 28% less DMLY

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compared with the mean of corresponding component monocultures. Mixture AE produced 193 and 72% more seed yield for leaf-harvested and non-leaf-harvested treatments, respectively, than the mean of corresponding component monocultures (Table 5). On-farm mixture BD produced 100% more DMLY than its corresponding component monocultures (Table 5). The mixture DE had 148% more seed yield in leaf-harvested rows, while mixture ABE produced 175% higher seed yield compared with its corresponding non-leaf-harvested component monocultures (Table 5). The majority of the few significant effects observed were from two-way mixtures, especially when evaluated on-station.

Variance of interaction effects

Cultivar mixtures, or the corresponding component monocultures, with low variance interaction effects are considered to maintain yield stability across different harvests. However, low-performing cultivars also had lower variance interaction effects. As DMLY values were substantially higher on-farm, the variance was also higher on-farm.

Despite average DMLY performance, complex mixtures always had the lowest variance of interaction effects compared with two-way mixtures and corresponding component monocultures (Fig. 1). The indeterminate types B and E had the highest on-station and on-farm variance, respectively. Local cultivar E and mixture ABCD had the lowest DMLY variance on-station; cultivar mixture ABE had the lowest DMLY variance on-farm (Fig. 1).

Discussion

Yield performance

In Tanzania, varietal mixtures are grown to help prolong harvest, increase income and improve dietary diversity. The overall performance of cultivar mixtures in this study compared to their corresponding component monocultures did not show any yield advantage nor a disadvantage for leaves or seed. These results agree with several studies on mixtures conducted with different crops (Erskine, 1977; Knott and Mundt, 1990; Hackett et al., 2006; Mille et al., 2006; Osman, 2006; Shorter and Frey, 2006; Swanston et al., 2006).

Among all cultivars tested, the local landrace check produced superior leaf yield, particularly on-farm. This result may partly be attributed to this indeterminate type having relatively more foliage, which creates a sink for solutes with less photosynthate channelled to seed development. Variation in leaf and seed yields may be attributed, in part, to architectural and canopy differences between determinate and indeterminate types. Cultivars constituting mixtures had horizontal/prostrate branching leaves for cultivars B and E, and acute/erect branching leaves for cultivars A, C and D. When planted together, variation in leaf morphology and canopy cover may have led to competition affecting leaf and seed yields. However, variation due to architectural differences may not always influence final yield components toward the same direction; cultivars may have various genetic characteristics of adaptive responses to stresses affecting biomass partitioning differently.

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During each leaf-harvesting, approximately 70% defoliation occurred. This practice is common with producers who engage in dual-purpose cowpea production, and where leaves are used more than seed (Mamiro et al., 2011). Following sequential leaf harvests a single seed harvest occurs at the end of the season, producing overall DM yield (leaves and seed) comparable to those of cultivars exclusively harvested for seed. Leaf-harvesting negatively affected seed development in all treatments (Table 4), corroborating findings by Karikari and Molatakgosi (1999) and Saidi et al. (2007). On average, seed yield was almost 30% less, in leaf-harvested treatments compared with non-leaf-harvested treatments. Leaf-harvesting reduces accumulation of carbon reserves due to reduced photosynthesis. When leaf-harvesting is carried out during seed development, a common practice, reduced accumulation of carbon reserves leads to smaller seed and lower seed yield. Saidi et al. (2007) observed that photosynthates are directed toward developing new leaves at expense of being stored for reproductive parts.

Mixture effects on yield

The relative mixture effect was measured by percent increase, or decrease, of mixtures over the mean yield of corresponding component monocultures. The majority of the few significant mixture effects on yield were from two-way mixtures. This indicates mixing abilities, where best mixture components could be identified for varieties that perform well in two-way mixtures, and especially under a maize-cowpea intercrop system. Mille et al. (2006) suggest that two-way mixtures should be screened to remove unfavorable pairs of varieties, and those that show complementarity should be selected for constructing more complex mixtures. Lopez and Mundt (2000) predicted yield performance of more complex mixtures from two-way mixtures.

Mixture effects on leaf yield stability

Yield stability is an advantage of cultivar mixtures (Finckh and Wolfe, 2006). Most farmers prefer varieties that produce leaves over a long time over those that have a high cumulative yield over a short period (Helland and Holland, 2001). Cowpea, as a leafy vegetable, could be more important if a regular year-round supply of leaves occurred, rather than a high yield from a single harvest (Tefera, 2006). In this study, successive leaf harvests tested mixture stability within a time period. Cultivar mixtures, or their corresponding monocultures, with low variations due to interaction effects, were regarded as stable. There was relatively higher yield stability across harvests for three- to five-way mixtures compared with two-way mixtures and monocultures on-station and on-farm (Fig. 1).

The stability established by more complex mixtures might have resulted from decreased interaction of cultivar mixture components with underlying environmental conditions due to complementarity of selected cultivars. The decrease in genotype× environment interaction is an advantage of mixtures over component monocultures, providing there is an increase in yield stability (Erskine, 1977). Some micro-climatic variation, for instance erratic rainfall observed in both locations, may have irregularly increased or decreased leaf yield stability in some treatments. This may help interpret yield variation of treatments between successive harvests, but only a decreased genotype×environment interaction would likely explain how the complex mixtures were able to maintain yields.

It is possible to find varieties that are equally or more stable than variety mixtures (Erskine, 1977) although their performance may vary by location (Fig. 1). The indeterminate landrace check (E) had very low variability on-station, but had the highest variability on-farm compared with other treatments, indicating that genotype was not stable across harvests. This also indicates how well the local landrace check could respond to more favorable conditions. Other cultivars were less leafy and had no quick response to changing environmental conditions. Finally, some yield variability between cultivar component monocultures and mixtures may be attributed to the ability of components to perform well under shading in intercropping systems.

The landrace check gave the best leaf yields and influenced the most positive mixture effects and stability on-station and on-farm, either as monoculture or in mixtures. The landrace check may have resulted from a long process of selection by producers from the semi-arid Dodoma region, and was best adapted for this highly variable environment. Complex mixtures were able to maintain more stable yields over time across successive leaf harvests compared with simple mixtures and component monocultures. This may reflect their greater ability to remain stable across environments, and potentially be used as an option for mixed cropping systems under variable climatic conditions. Multiple leaf harvests reduced seed yields over non-leaf-harvested plants, however, overall DM yield (leaves and seed) is comparable to that of cultivars exclusively harvested for seed. It seems that none of the new cowpea cultivars contribute to further improvement. Further studies are necessary to investigate stability of complex mixtures across several environments, and on an optimal defoliation level in terms of frequency and timing that would not substantially affect final seed yield to identify suitable dual-purpose cowpea varieties.

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Figure 1: Variance of interaction effects of mean dry matter leaf yields (DMLY) in cowpea cultivar mixtures and corresponding 5 component monocultures evaluated (a) on-station at VRTC and (b) on-farm in Veyula village in Dodoma, Tanzania during 2007-2008. A = 'Ex-Iseke', B = 'UG-CP-9', C = 'Dakawa', D = 'T93K204529', E=Local cultivar.

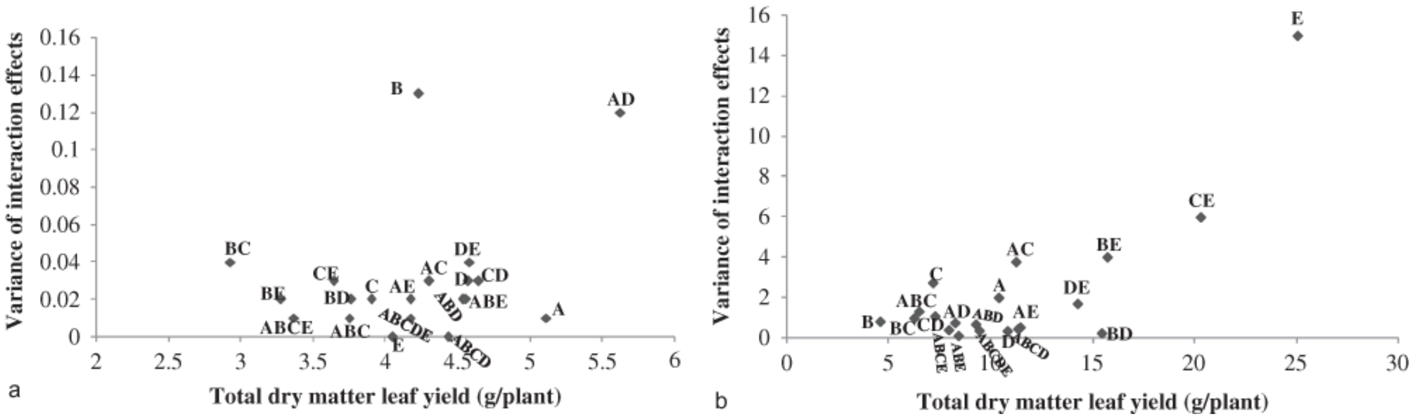

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Table 1: Soil characteristics[a] of on-station trial field at Makutupora Viticulture Research and Training Centre (VRTC) and on-farm trial field at Veyula village, Dodoma Region, Central Tanzania.

Location	Particle size distribution			Texture class	Total N	OC[b]	Zn	Br1 Ext. P[b]	CEC[b]	Exchangeable bases [Cmol(+)·kg^{-1}]		
	Clay %	Silt %	Sand %		%	%	mg·kg^{-1}	mg·kg^{-1}	Cmol(+)·kg^{-1}	Ca^{2+}	Mg^{2+}	K^{+}
VRTC (on-station)	32	5	63	SCL[b]	0.08	0.90	1.64	38.79	12.8	4.07	2.39	1.11
Veyula Village (on-farm)	22	3	75	SCL[b]	0.04	0.52	0.43	21.39	10.4	0.49	0.26	0.36

[a] Sokoine University of Agriculture, Morogoro, Tanzania.

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[b] SCL = sand clay loam; OC = organic carbon; Br1 Ext. P = Bray 1 extractable Phosphorous; CEC = cation exchange capacity.

Table 2: Characteristics of cowpea cultivars used for the mixture study in Dodoma Region, Tanzania.

Experimental ID	Original identifier	Status	Growing type	Seed source
A	Ex-Iseke	Experimental line	Indeterminate (I)[a]	AVRDC-RCA[c]
B	UG-CP-9 (KOL42)	Experimental line	Indeterminate (I)	AVRDC-RCA
C	Dakawa	Cultivar	Determinate (D)	AVRDC-RCA/ARI-Ilonga[d]
D	IT93K204529	Experimental line	Semi-Indeterminate/ determinate (S)	AVRDC-RCA/IITA[e]
E	Local Cultivar	Landrace	Determinate (D)[b]	Dodoma market

[a] Observed to be determinate;

[b] Observed to be indeterminate;

[c] AVRDC-RCA – The World Vegetable Center, Regional Center for Africa;

[d] ARI-Ilonga - Agricultural Research Institute at Ilonga, Tanzania;

[e] IITA - International Institute of Tropical Agriculture.

Table 3: Selected treatments of cultivar mixtures evaluated. Each treatment was intercropped with maize variety 'Situka M1'.

Treatment ID	Component	Treatment ID	Level 1 mixtures	Treatment ID	Level 2 mixtures
1	A	6	A+C	15	A+B+C
2	B	7	A+D	16	A+B+D
3	C	8	A+E	17	A+B+E
4	D	9	B+C	18	A+B+C+D
5	E	10	B+D	19	A+B+C+E
		11	B+E	20	A+B+C+D+E
		12	C+D		
		13	C+E		
		14	D+E		

Table 4: Cultivar mixture effects on dry matter leaf yield (DMLY) and seed yield from leaf-harvested (LH) and non-leaf-harvested (NH) cowpea plants tested on-station and on-farm in Dodoma Region, Tanzania.

Source of variation		On-station				On-farm			
Cultivar mixture	Growth habit	DMLY (g/plant)	Seed yield (LH) (g/plant)	Seed yield (NH) (g/plant)	Mean seed yield (LH& NH) (g/plant)	DMLY (g/plant)	Seed yield (LH) (g/plant)	Seed yield (NH) (g/plant)	Mean seed yield (LH& NH) (g/plant)
A	Determinate (D)	5.11	8.98	18.97	13.98	10.44	9.49	20.97	15.23
B	Indeterminate (I)	4.23	9.77	16.17	12.97	4.63	6.52	13.49	10.01
C	Determinate	3.90	5.52	16.30	10.91	7.22	10.27	17.90	14.09

	(D)								
D	Semi-determinate (S)	4.57	4.43	14.03	9.23	10.87	7.79	28.23	18.01
E	Indeterminate (I)	4.05	1.67	5.27	3.47	25.07	9.19	10.34	9.77
AC	(D+D)	4.30	7.48	19.33	13.41	11.28	10.00	25.65	17.83
AD	(D+S)	5.62	6.96	23.09	15.03	8.30	9.86	16.77	13.32
AE	(D+I)	4.17	14.16	20.88	17.52	11.49	7.39	19.31	13.35
BC	(I+D)	2.93	3.63	12.83	8.23	6.30	7.92	17.32	12.62
BD	(I+S)	3.76	2.64	15.11	8.88	15.48	7.44	25.50	16.47
BE	(I+I)	3.28	10.68	7.34	9.01	15.76	3.46	17.41	10.44
CD	(D+S)	3.64	2.99	12.25	7.62	7.32	6.59	15.70	11.15

CE	(D+I)	4.64	2.71	12.35	7.53	20.32	7.53	24.64	16.09
DE	(I+S)	4.58	3.70	8.37	6.04	14.30	18.95	15.58	17.27
ABC	(D+I+D)	3.75	8.00	18.26	13.13	6.54	5.45	24.24	14.85
ABD	(D+I+S)	4.53	6.58	16.04	11.31	9.31	9.39	23.12	16.26
ABE	(D+I+I)	4.55	6.65	12.59	9.62	8.47	13.99	47.22	30.61
ABCD	(D+I+I+S)	4.43	9.86	16.07	12.97	11.38	7.18	17.09	12.14
ABCE	(D+I+D+I)	3.37	5.74	15.50	10.62	7.99	11.53	24.35	17.94
ABCDE	(D+I+D+S+I)	4.17	7.71	18.08	12.90	9.49	7.82	25.95	16.89
F-Test		*	*	*		**	ns	ns	

$LSD_{0.05}$	1.22	6.50	8.57		8.31	8.08	22.35

*, **, and *** - significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$, respectively.

[a] A = 'Ex-Iseke', B = 'UG-CP-9', C = 'Dakawa', D = 'IT93K2204529', E=Local landrace check.

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Table 5: Relative mixture effects (RME, in percent) and leaf-harvesting effects on dry matter leaf yield (DMLY) and seed yield of leaf-harvested (LH) and non-leaf-harvested (NH) cowpea evaluated on-station and on-farm in central Tanzania.

Growth habit mixture [a]	Component cultivar [b]	DMLY RME (%)[c]	DMLY F-test	Seed yield (LH) RME (%)[c]	Seed yield (LH) F-test	Seed yield (NH) RME (%)[c]	Seed yield (NH) F-test
				– On station –			
D + D	AC	-5	0.71	3	0.94	10	0.65
1+ I	BE	-21	0.12	92	0.15	-31	0.37
D+ S	AD	16	0.16	4	0.93	40	0.08
	CD	-14	0.28	-40	0.49	-19	0.44
D + I	AE	-9	0.46	193	0.01	72	0.02
	BC	-28	0.04	-52	0.17	-21	0.36

	CE	17	0.23	-19	0.83	15	0.67
I + S	BD	-15	0.25	-63	0.13	0	1.00
	DE	6	0.62	32	0.76	-13	0.73
D + I + D	ABC	-15	0.21	-1	0.97	6	0.75
D + I + S	ABD	-2	0.84	-15	0.67	-2	0.92
D + I + I	ABE	2	0.86	-4	1.00	-15	0.80
D + I + D + S	ABCD	0	0.97	37	0.31	-2	0.93
D + I + D + I	ABCD	-22	0.06	-10	0.82	9	0.70
D + I + D +S + I	ABCDE	-5	0.68	29	0.50	28	0.24

– On farm –

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D + D	AC	28	0.52	1	0.97	32	0.53
I + I	BE	6	0.81	-47	0.49	46	0.58
D + S	AD	-22	0.53	17	0.73	-32	0.43
	CD	-19	0.65	-27	0.51	-32	0.45
D + I	AE	-35	0.10	-13	0.79	23	0.71
	BC	6	0.92	-6	0.90	10	0.87
	CE	26	0.27	-15	0.75	75	0.29
I + S	BD	100	0.05	4	0.94	22	0.64
	DE	-20	0.33	148	0.01	-19	0.71
D + I + D	ABC	-12	0.80	-38	0.34	39	0.46
D + I + S	ABD	8	0.85	18	0.68	11	0.81

D + I + I	ABE	-23	0.17	71	0.11	175	0.00
D + I + D + S	ABCD	37	0.37	-16	0.69	-15	0.73
D + I + D + I	ABCE	-32	0.27	36	0.38	55	0.33
D + I + D + S + I	ABCDE	-18	0.52	-6	0.88	42	0.38

[a] Growth habit, D = determinate, I = Indeterminate, S = semi-determinate

[b] A = 'Ex-Iseke', B = 'UG-CP-9', C = 'Dakawa', D = 'IT93K204529', E = Local landrace check.

[c] Difference between mean of mixture and mean of component monocultures is significant at $P \leq 0.05$.