academicJournals

Vol. 12(40), pp. 2969-2975, 5 October, 2017
DOI: 10.5897/AJAR2017.12592
Article Number: FEC816A66207
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Yields and forage nutritive quality of high-yielding dual purpose cowpea (*Vigna unguiculata* L. Walp.) varieties in the Sahelian low-input cropping system

Ibrahim Ali[1*] and Pasternak Dov[2]

[1]Office Chérifien des Phosphates (OCP Africa) P. O. Box 12404 Niamey, Niger.
[2]International Adviser Drylands Agriculture, 16/12 Harav Goren St. Rishon LetZion 75753, Israel.

Received 13 July, 2017; Accepted 31 August, 2017

Cowpea is a major food legume crop in the Sahel with tolerance to drought and to the nutrients-leached acid sandy soils of this region. However, the existing cowpea varieties grown by farmers are low yielding and pest sensitive which make them unsuitable to satisfy farmer's needs. The objective of this study was to identify high-yielding cowpea varieties which are well adapted to the Sahelian ecosystem. Eight dual-purpose cowpea varieties from various sources were tested with and without insects control in Niger during two cropping seasons (2005 and 2007). In 2005, a relatively wet year, KVX 745-11-P and four other varieties (ISV 20, ISV 40, ISV 128 and IT98D-1399) gave highest grain yields ranging from 1220 to 1521 kg ha^{-1}. In the dry year (2007), the highest grain yield was recorded with ISV 128. There were also significant differences in forage yield between varieties in both the wet and dry year. Application of insecticide increased cowpea grain yields significantly. Cowpea produced without insect control (spray) resulted in high grain yields losses and increased cowpea fodder yields in both years. KVX 745-11-P was the most sensitive variety to insects whereas IT98D 1399 seemed to be relatively the most insect tolerant variety. There were no significant differences between varieties in most forage quality parameters. These results provide the possibility of a potential extension of dual-cowpea varieties for improved food security in the Sahel.

Keywords: Dual purpose cowpea, grain yield, fodder quality, sahel

INTRODUCTION

Cowpea is a major pulse crop in the Sahel and contributes to the nutrition and livelihoods of millions of people living in this region. It provides protein rich grains for human consumption and quality forage for animal feed making it a dual-purpose crop (Dube and Fanadzo, 2013). The dual-purpose character of cowpea makes it a very attractive crop where land is becoming scarce (Singh et al., 2003). It helps smallholder farmers who

*Corresponding author. E-mail: ibabaye@gmail.com. Tel: +227 96 26 73 74.

have little land to achieve food security and feed their animals from the same area. Furthermore the dual purpose cowpea varieties have the potential of bringing nitrogen (N) into the farming system through biological fixation and thereby enhancing fertility status of the soils (Anele et al., 2010).

Cowpea is well adapted to Sahelian ecosystems and it is relatively tolerant to drought and can grow in the poor sandy soils (Belko et al., 2014). Unfortunately the existing varieties grown by farmers are low yielding and pest sensitive which make them less suitable to satisfy farmers' needs.

According to Calzadilla et al. (2013), the population in Sub-Saharan Africa could double by 2050 increasing agricultural consumption by 2.8% annually until 2030, and by 2.0% annually from 2030 to 2050. There is, therefore a need to develop and make available to the farmers, high-yielding cowpea varieties in order to ensure food security. In order to achieve this objective, the International Institute of Tropical Agriculture (IITA) conducted intensive breeding of cowpeas varieties with emphasis on high yield potential for grain as well as fodder with tolerance to major biotic and abiotic stresses (Singh et al., 2003). Today many of the varieties used in West Africa originated from IITA. The breeding work by IITA was conducted mostly in the region of Kano in North Nigeria where average annual rainfall is around 900 mm. This is much higher than the average rainfall (350 to 500 mm per year) in the Sahelian regions where cowpeas are produced. Thus cowpea varieties selected in Kano might not be tolerant to the drier conditions as those selected in Niger. There is a need of identifying cowpea varieties more adapted to the Sahelian zones.

On the other hand, annual cowpea grain yield in farmers' fields, was less than 500 kg ha^{-1} (Sambo et al., 2013) while in research stations potential yields are more than 1,500 kg ha^{-1} of grain and 2,500 kg ha^{-1} of fodder could be recorded (Singh et al., 2003). Low yields in farmers' fields are caused by a multitude of reasons including low soil fertility and low yielding varieties. However, insect attack is a major reason for these low yields. In order to increase cowpea yields and ensure food security in the Sahel, this study was carried out to identify high-yielding dual-purpose cowpea varieties that might fit to the Sahelian conditions.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the Sadoré Research Station of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Niger. Sadoré is situated at 13° 15'N and 2° 18'E and 240 m above sea level. The climate is characterized by a rainy season that occurs between June and September, and a dry season that prevail during the rest of the year. The mean annual rainfall at Sadoré is 560 mm (Sivakumar and Salaam, 1999). The average temperature is 29°C (ICRISAT climate database). The soil is classified as a sandy silicious isohyperthemic Psammentic Paleustalf. The chemical characteristics of the composite soil samples taken from 0 to 20 cm depth of the experimental site in 2005 indicate that the soil is typically low in organic C (0.2%), total N (151 mg/kg) and in available phosphorus was 13.7 mg/kg with a pH-H_2O value of 5.1.

Experimental design and data collection

The experiment was conducted during the rainy season in 2005 and 2007. A randomized complete block design arranged in a split plot with five replications was used. The main plot treatment factor was the insecticide spray (*Lamda- cyhalothrine* 25 EC) at two levels (with and without insecticide spray) and the subplots consisted of eight dual purpose cowpea varieties. Each subplot measured 8 m x 8 m (32 m^2). In 2005, cowpeas were planted in a site that was left fallow for five consecutive years. In 2007 it was planted near the 2005 field in a site that was left fallow for six years. The cowpea varieties were dibbled at spacing of 1 x 0.5 m with three seeds per hole. The subplots were separated from each other by 2 m wide borders to reduce spray drift between plots.

Sowing was done at the onset of the rains on June 27th and July 13rd in 2005 and 2007, respectively. The cowpea varieties used for the test came from various sources. Two varieties from IITA (IT98D-1399 and IT98K-131-2), one variety (KVX745-11-P) from Institut National de l'Environnement et de Recherches Agricoles (INERA) breeders in Burkina Faso, four varieties bred and selected at ICRISAT-Niger (ISV 128, ISV 20, ISV 28 and ISV 40) and one variety introduced from Mexico (Ejetero V11). For each experimental year, the field received 30 kg N ha^{-1}, 13.1 kg P ha^{-1} and 24.9 kg K ha^{-1} as NPK 15-15-15. Fertilizer was broadcasted and incorporated into the soil by a disk plough. Spraying started with the appearance of the first flower buds. Four consecutive spraying were done at seven days interval between sprays.

Daily rainfall was recorded with a rain gauge located in the experimental field. Days to flowering and maturity were determined for each variety. Harvesting was done in September to October. To determine grain yield and fodder yield, cowpea was harvested from an area of 6 x 6 m within each subplot. The pods were harvested and threshed and all the haulm collected. The seeds were sun-dried thereafter weighed and expressed in kg ha^{-1}.

Plant sampling and analysis

Plants samples were taken from each treatment at harvest and analyzed for feed value. The oven-dried cowpea haulms were milled and pass through a 1 mm sieve then analyzed for lignin content according the procedures of Van Soest and Robertson (1985). Hemi-cellulose and cellulose were calculated as the differences NDF − ADF and ADF − lignin, respectively (Hossain et al., 2013). Organic matter digestibility (OMD) was determined by the *in vitro* gas production technique calibrated with standards obtained *in vivo* (Menke et al., 1979). The total nitrogen content in the different cowpea plant parts was determined using the Kjeldahl digestion procedure (Houba et al., 1995) and the percent protein content was estimated from the Kjeldahl (crude protein % = Total N % x 6.25).

Data analysis

Prior to analysis of variance, the data were checked for normality using residual plots in GENSTAT v.9 (Lawes Agricultural, 2007). Thereafter, the data collected were subjected to analysis of variance in GENSTAT v.9 using a split plot treatment structure. Model of ANOVA included year, cowpea varieties, spray treatment

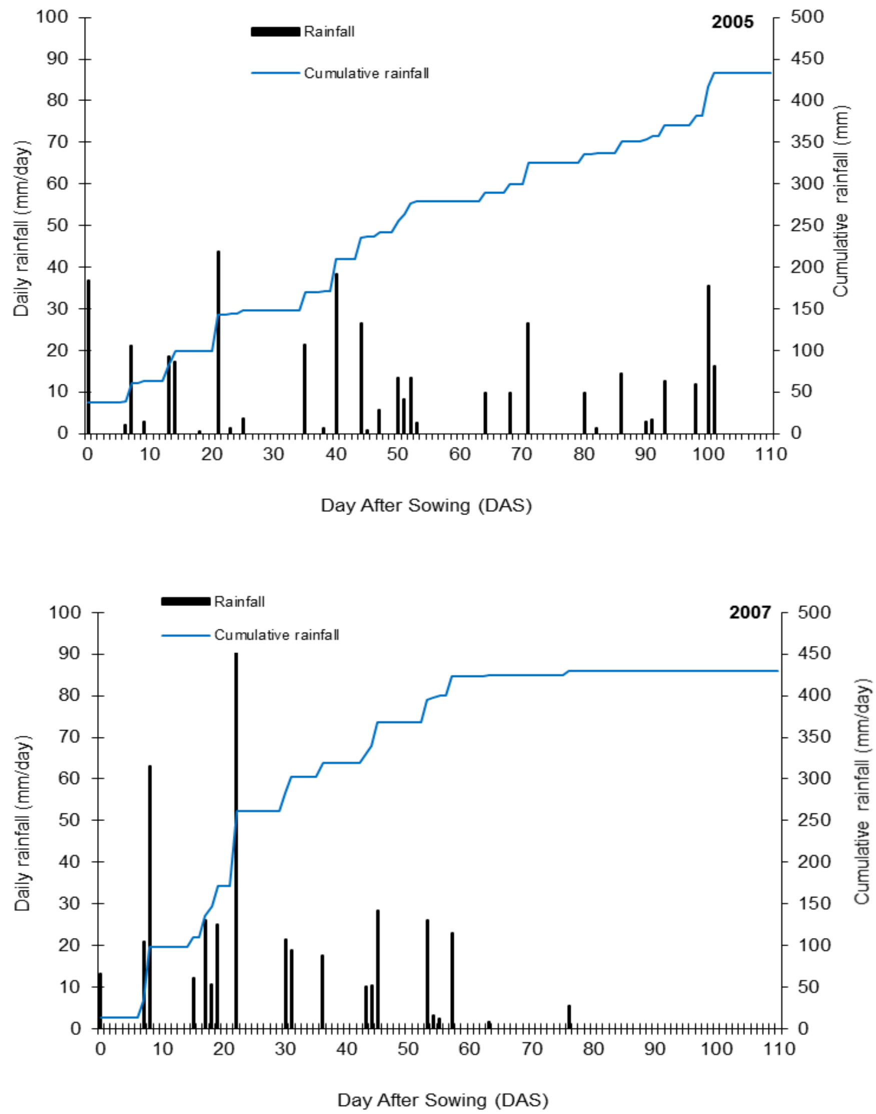

Figure 1. Cumulative rainfall and rainfall distribution during 2005 and 2007 cowpea production season.
Source:

and their interactions.

RESULTS AND DISCUSSION

Rainfall distribution

In 2005, rain was evenly distributed during the production period (wet year) but in 2007 (dry year) rain stopped being regular from 58 days after sowing (Figure 1). The rainfall recorded during the cropping seasons 2005 and 2007 were 433 mm and 430 mm, respectively (Figure 1). These quantities of rainfall were below the long-term rainfall average (560 mm) recorded in the study area (Ibrahim et al., 2015a). Even though, the cumulative rainfall recorded was almost equal in both years, there were large differences in rainfall distribution between the two rainy seasons. In 2005, rains were evenly distributed throughout the cropping period whereas in 2007 the last effective rain occurred 58 days after planting.

Cowpea varieties developmental stages

Number of days to flowering and days to maturity for cowpea varieties are presented in Table 1. Days to flowering varied from 45 to 48 days after sowing among the eight varieties. There were no statistical differences

Table 1. Number of days to flowering and days to maturity for eight dual purpose cowpeas varieties in 2005.

Varieties	Days to flowering	Days to maturity
Ejetero V11	47 ± 2	65 ± 1
ISV128	45 ± 2	65 ± 1
ISV20	45 ± 2	72 ± 1
ISV28	47 ± 2	72 ± 1
ISV40	45 ± 2	69 ± 1
IT98D-1399	45 ± 2	66 ± 1
IT98K-131-2	48 ± 1	70 ± 1
KVX745-11-P	48 ± 2	68 ± 1
Probability values (5%)	0.078	< 0.001

± Standard error.

among the cowpea varieties in terms of number of days to flowering. However, the number of days to maturity varied significantly ($P < 0.001$) among the cowpea varieties. Varieties ISV 128 and Ejetero were the earliest cowpea varieties (65 days after sowing) compared to other varieties used in the current study. Early maturity is an important parameter to be considered in the selection of cowpea varieties particularly in the Sahelian zones characterized by unpredictable rainfall pattern. The cowpea varieties tested in the current study appear to be earlier in maturity compared to the cowpea varieties recommended and cultivated by farmers in Niger with days to maturity varying from 80 to 89 days (Dugje et al., 2009).

Cowpea grain and forage yields

Grains and forage yields during the two experimental years are given in Table 2. There was a significant ($P < 0.001$) year-effect on cowpea grain yield. In 2005, grains yield ranged among varieties from 841 to 1522 kg ha^{-1}. In 2007, grain yields were much lower and ranged from 405 to 990 kg/ha. The higher grain yield recorded in 2005 could be attributed to better rainfall distribution in this year as compared with 2007 (Figure 1). Several studies have reported seasonal yields differences particularly in the Sahel due to inter-annual rainfall distribution (Anele et al., 2011; Ibrahim et al., 2015b). In 2005, sprayed KVX 745-11-P gave the highest grain yield (1522 kg ha^{-1}) that did not differ significantly from the yields of IT 98D-1399, ISV 40 and ISV 128. In 2007, which was relatively a drier year, sprayed ISV 128 (990 kg ha^{-1}) and IT 98D-1399 recorded the highest grain yields than all other varieties. An explanation for the relatively drought tolerance of ISV 128 and to a lesser extent of IT98D-1399 could be a result of deeper roots that exploit water in the soil more than drought sensitive varieties as was demonstrated for a drought tolerant cowpea variety by Matsui and Singh (2003). In both years, grains yield was significantly higher in sprayed plots than in non-sprayed plots. Cowpea produced without spray resulted in high grains yield losses from 93% in 2005 to 63% in 2007. The findings of this study are consistent with those of Ajeigde et al. (2005) who reported a huge cowpea yield losses in the absence of insect control. Generally, all varieties tested were sensitive to insects, some more than others. Insects' damage was relatively severe in KVX 745-11-P plots where the grain yield of non-sprayed plants represented only 1.2 and 8% of the yield of sprayed plants in 2005 and 2007, respectively. Although potential grain yield of this variety is high, it can only be expressed if treated with insecticides. The variety IT98D-1399 was found to show promising tolerance to flower insects particularly thrips and recorded a relatively high yield in the absence of insecticide application. This study did not provide the opportunity for better understanding of the mechanism underlying the behavior of IT98D-1399 in thrips tolerance. Further study aiming at determining the mechanisms of tolerance operating in IT 98D-1399 is therefore needed.

There was significant ($P < 0.001$) variability between varieties in forage yields. In both years forage yields of the untreated plants were higher than the yields of sprayed plants. In the absence of insect control, cowpea fodder yields have increased by 31% and 23% in 2005 and 2007, respectively. The lower fodder yields recorded with sprayed plots could be attributed to the leaves defoliation as a result of the longer duration for pods to be matured. Diversion of photosynthates to seed production may partly affect foliage production. In 2005, the plots of ISV 20 sprayed with insecticide gave the highest forage yield (2666 kg ha^{-1}) that was not statistically different from forage yields of ISV 40, ISV 128 and KVX 745-11-P. There was a significant year-effect on cowpea forage yields. Cowpea fodder yield in wet season (2005) was approximately 58% greater than in drier season (2007). The seasonal yield variability could be attributed to the good rainfall distribution observed throughout the growing period in 2005 (Figure 1) which

Table 2. Grain and forage yields of sprayed and non-sprayed cowpeas varieties during two growing seasons.

Cowpea variety	Spray	Grain yield (kg/ha)		Fodder yield (kg/ha)	
		2005	2007	2005	2007
Ejetero V11	Yes	841±78	405±26	1333±190	557±64
	No	14±5	99±9	1740±259	910±60
ISV 128	Yes	1341±169	990±156	3264±337	1115±244
	No	129±96	397±89	2930±196	1536±169
ISV 20	Yes	1220±141	538±35	2666±254	1755±109
	No	16±3	86±6	3708±566	2130±180
ISV28	Yes	972±74	432±66	1334±187	1364±120
	No	29±13	55±19	3187±100	1555±153
ISV 40	Yes	1369±267	712±56	2594±202	1533±157
	No	128±69	203±24	3625±196	1593±115
IT 98D-1399	Yes	1488±103	753±75	1542±157	875±95
	No	239±71	309±19	2719±146	1298±212
IT98K-131-2	Yes	755±41	638±35	1570±180	1125±145
	No	82±22	198±32	3104±393	1722±172
KVX 745-11-P	Yes	1521±122	672±90	2240±256	1277±146
	No	18±3	54±19	2864±279	1677±147
Probability values					
Variety (V)		<0.001		<0.001	
Insecticide (I)		<0.001		<0.001	
V × I		0.003		0.006	
Year (Y)		<0.001		<0.001	
Y × V		0.001		0.048	
Y × I		<0.001		0.001	
Y × V × I		0.055		0.037	
CV (%)		26.8		24.2	

CV, Coefficient of variation; ± Standard error.

ultimately favoured better plant growth and biomass production.

Cowpea fodder quality

Fodder quality parameters are given in Table 3. Varieties and the insecticide had no significant effect on cowpea fodder quality. *In vitro* OMD ranged from 600 to 643 g/kg in sprayed and non-sprayed plots with the highest value of *in vitro* OMD being obtained with the ISV 128 variety. Crude protein (CP) content varied from 108 to 138 g/kg and from 114 to 126 g/kg between the sprayed and unsprayed plots. All the cowpea varieties had CP concentrations greater than 80 g/kg DM, the level below which voluntary intake of tropical forages is reduced (Minson, 1981). Kaasschieter et al. (1998) reported CP values for cowpea ranging from 78 to 217 g kg^{-1} DM. Cowpea haulms of the varieties used in this study had higher CP content than those used by Savadogo et al. (2000). Such variation in quality of cowpea haulms may be due to factors such as genetic characteristics, environment (soil characteristics, rainfall) and crop management (Singh, 1995). There were no significant differences between varieties and insecticide treatment and their interaction in relation to lignin and hemi- cellulose.

Table 3. Fodder quality parameters.

Varieties	Spray	*In vitro* OMD (g/kg)	Crude protein (g/kg)	Lignin (g/kg)	Cellulose (g/kg)	Hemi cellulose (g/kg)
Ejetero V11	Yes	600±3	138±1	68±0	257±2	166±3
	No	599±2	122±3	73±1	243±1	149±2
ISV 128	Yes	643±5	108±1	56±2	190±1	128±1
	No	643±1	114±1	65±1	175±1	110±1
ISV 20	Yes	643±3	120±4	67±1	249±3	134±1
	No	640±3	125±2	65±3	252±2	96±1
ISV28	Yes	615±1	119±1	67±1	282±2	89±2
	No	614±4	139±2	66±1	257±1	83±1
ISV 40	Yes	607±5	120±3	66±1	283±2	100±2
	No	609±3	119±1	58±2	245±1	117±3
IT 98D-1399	Yes	598±1	114±2	65±1	264±1	132±1
	No	599±3	126±2	69±3	226±1	130±1
IT98K-131-2	Yes	601±1	116±1	62±2	280±2	92±2
	No	605±1	119±1	54±1	238±3	104±2
KVx 745-11-P	Yes	607±4	114±4	55±0	261±1	110±2
	No	610±5	126±2	60±1	219±1	104±1
Probability values						
Variety (V)		0.676	0.46	0.552	0.087	0.087
Insecticide (I)		0.496	0.136	0.783	0.057	0.081
(V x I)		0.943	0.302	0.766	0.291	0.067
CV (%)		7.8	5.3	5.1	6.4	4.1

CV, Coefficient of variation; ± Standard error.

Cellulose concentration was significantly higher in plants sprayed with insecticides.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

The authors gratefully appreciate and thank Mr. Moustapha Amadou, Mr. Saidou Abdoussalam and Hassane Bissala Yahaya from ICRISAT-Niger for their technical support.

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