Evaluation of cowpea [Vigna unguiculata (L) Walp.] lines for high grain and fodder yields in the dry season of Niger republic

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ABSTRACT

Cowpea grains constitute a nutritious food to humans, while resource-poor farmers use its fodder and shell in fattening livestock during the dry season in Niger. Owing to the high price of these commodities, especially in the hot, dry season, the development and adoption of dual-purpose varieties adapted that period may significantly lower the cost of cowpea products to farmers. To that end, 12 cowpea genotypes were evaluated for high grain and forage yield at three INRAN research stations during the hot, dry season of 2021. The data collected were analyzed with R software and the results revealed significant differences among genotypes for grain and fodder yields. IN17_142 and IN15_62 turned out to be the best performing cultivars with 1198.3 kg/ha and 1187.5 kg/ha as mean grain yield and 3790.0 kg/ha and 3542.0 kg/ha in terms of mean fodder yield. However, above 2 and 6 tons mean grain and fodder yields per hectare were recorded by each of these two genotypes at Maradi. High positive relationships were detected between grain and fodder yields, as a result, the winning lines are the same for the two traits. Dual-purpose varieties suited for cowpea production in the hot dry season of Niger are detected in this work and its adoption by farmers may help boost the production.

1. Introduction

Cowpea [Vigna unguiculata (L) Walp.] is the second crop in terms of production and area under cultivation in Niger republic (Annuaire Statistique du Niger, 2019). It is among the primary staple food in rural and sub-urban communities as it is consumed as a vegetable, soup, fried (kossai), bread, pizza and mixed with rice (Ibro et al., 2009, 2011; Seydou et al., 2014). Its fodder and shell serve as high-quality feed for livestock, especially during fattening. Furthermore, cowpea is a major source of income for small scale farmers. As one of the major cash crops in Niger, it is the second in terms of foreign earnings for the country after rice (Annuaire Statistique du Niger, 2019). The cowpea production in Niger is almost exclusively done in the rainy seasons. However, it suffers enormous setbacks from numerous constraints such as high drought incidence, low soil fertility, insects, parasitic weeds and diseases. In the dry season, cowpea grain and fodder prices are usually peak due to short supply in markets. An alternative in reducing the gap between supply and demand of cowpea products throughout the year could be cowpea production during the dry season. Ali et al. (2009) stated that dry-season cowpea production could help curtail the price of cowpea grain and supply livestock with fodder during the off-season. During the dry season, cowpea does not suffer damage from main production constraints, which cause significant yield reduction in the rainy season. Dual-purpose varieties that produce a high yield in the dry season have been reported in Nigeria (Ali et al., 2009, Inaizumi et al., 1999) and the Niger republic (Souleymane et al. 2017, 2018). A high rate of adoption of IT89KD-288, a dual-purpose variety with high performance in the dry season, was observed by Inaizumi et al., (1999) in Kano State. They stated that over 1500 farmers adopted the variety only four years after accidentally obtaining its seeds.

IITA and INRAN introduced dry-season cowpea production technology in the Fadama areas of Radi and Adrawa in the Niger republic. This initiative involved 12 pilot farmers, but the following season many farmers purchased the seeds these seeds to embark on this activity (https://www.iita.org/news-item/farmers-embrace-dry-season-cowpea-production-technology-niger-republic/). The benefits that farmers obtained from dry-season production of dual-purpose cowpea varieties include food security during a critical period of the year, crop diversification, cash, good quality fodder at a time where the price is high, and pasture is scarce (Inaizumi et al., 1999). Irrigated lands in the Niger republic are presently used for vegetables, wheat and rice production. The introduction of dual-purpose cowpea production into rice-wheat,
rice-vegetable and vegetable-vegetable systems could help in improving soil fertility and breaking insect pests and disease cycle (Ali et al., 2009). Also, the water requirement of cowpea is low, and no fertilizer is needed to obtain a high yield. Dry-season dual-purpose cowpea production can offer excellent opportunities to farmers provided appropriate varieties are available. The objective of the present work is to identify cowpea lines with high grain and fodder yield under hot, dry season climatic conditions in the Niger republic.

2. Materials and methods

2.1. Study sites

The study was carried out under irrigation at Kalapaté (13°12’ N and 2°56’ E), Tara (11°53’ N and 3°20’ E) and Maradi (15°26’N and 8°33’E).

2.2. Plant materials

It consisted of 11 newly developed lines and one check. The new lines were developed at Institut National de la Recherche Agronomique du Niger (NRAN). Nine of them were obtained from two biparental crosses through the bulk selection method, while the others were selected from farmers’ varieties using the pure selection method (Table 1.).

2.3. Methods

The trials took place from February to May in the dry season, extending from October to June. Seeds were treated with fungicide before planting. Two seeds were planted per hill and thinned to one plant three weeks later. The experimental design was a 3 × 4 alpha lattice with three replications. The plot size was 16 m² with 0.5 m as intra and inter rows spacings. The plants were watered twice a week, and no fertilizer was applied. Weeds were manually controlled two to three times using hoes while Emitoc (Enamectine benzoate 50 g/kg) and Pacha (Acetamipride 10 g/l, Lambda-cyhalothrin 15 g/l) were used in dealing with insects.

Data were collected on days to first flower appearance, days to 50% flowering, days to 50% maturity, pod yield (pod dry weight per plot), grain yield (seed dry weight per plot), fodder yield (fodder weight per plot), shell yield (shell weight per plot), harvest index (seed weight per plot divided by fodder and shell weights per plot). All the data collected per plot were later extrapolated to ha.

R version 3.6.3 (2020-02-29) was used in data analysis. The packages agricolae “was loaded for GxE heatmaps follow: library (agricolae)
libs (lattice)
redblue < - colorRampPalette (c ("firebrick", "lightgray", "#375997"))

| S/N | ID   | Designation   | Pedigree               |
|-----|------|---------------|------------------------|
| 1   | G1   | IN17-142      | NDiambour x IT84522-46-6 |
| 2   | G2   | IN17-125      | NDiambour x IT84522-46-6 |
| 3   | G3   | IN15-118      | Pure line              |
| 4   | G4   | IN17-17       | NDiambour x IT84522-46-6 |
| 5   | G5   | IN17-82       | NDiambour x IT84522-46-6 |
| 6   | G6   | IN17-10       | NDiambour x IT84522-46-6 |
| 7   | G7   | IN17-132      | NDiambour x IT84522-46-6 |
| 8   | G8   | IN17-03       | G118 x IT87D-1083      |
| 9   | G9   | TN5-78 (check)| Pure line              |
| 10  | G10  | IN15-62       | Pure line              |
| 11  | G11  | IN17-28       | NDiambour x IT84522-46-6 |
| 12  | G12  | IN17-77       | G150 x IT87D-1083      |

The kernel density estimation was used to determine grain and fodder yields distribution according to environment with the help of package “ggplot2”.

library (ggplot2)
ggplot (SChaude_21, aes (x = rdt.gr, fill = sites)) +
goom_density (alpha = 0.4) +
labs (title = "Grain yield distribution by environment")

The package “ggplot2” was also used to display the relationship between grain and fodder yields in a line graph.
ggplot (alph, aes (x = m50, y = rdt.gr)) +
goom_point (color = "steelblue") +
goom_smooth (method = "lm")

3. Results

In terms of genotypes by environment interactions, significant differences were detected for all the traits (Table 2.). The environments were significantly different (p < 0.001) for grain yield, fodder yield, shell yield and harvest index. Significant genotypic differences were also observed for grain and fodder yields (p < 0.001) and shell yield (p < 0.05); however, the genotypes were not significantly different with regard to harvest index.

Nevertheless, G x E was more significant in grain and shell yields than in the other traits. The change in winning genotypes from one site to another regarding grain and fodder yields is illustrated by the heatmaps in Figure 1 below. It shows that the highest yielding lines are G3 (IN15-118) at Kalapaté, G10 (IN15-62) at Maradi and G7 (IN17-132) at Tara regarding grain yield. In terms of fodder yield, the best performing genotypes are G1 (IN17_142), G3 (IN15-118) and G4 (IN17_17) at Maradi, Kalapaté, and Tara, respectively (Figure 1).

The significance of G × E interactions in the case of shell yield was not high because a single genotype won at two out of the three sites. G10 was the top-performing line at both Kalapaté and Maradi, while G6 turned out to be the best at Tara (Figure 2). In general, a change of rank of genotypes was observed from one site to another. However, the position of G8 remained almost constant as it recorded low shell yield at all the locations.

The density plot (Figure 3) showed that the genotypic variability in grain and fodder yields changed with the environment. Considerable variability was observed at Maradi and Kalapaté compared to Tara, where the lines’ performance was quite similar. Maradi and Kalapaté are the best sites for discriminating power among genotypes. These two environments seemed to give much information concerning the differences between tested lines with respect to grain

Table 2. Level of significance of factors with respect to traits.

| SOV   | Gyield | Fyield | Shyield | HI  |
|-------|--------|--------|---------|-----|
| Genotypes | 542553*** | 4735663*** | 43457* | 0.02572 |
| Environments | 16316840*** | 142163592*** | 1776961*** | 0.21432*** |
| Replications | 1009125*** | 6747689*** | 151986*** | 0.01758 |
| Block     | 38179   | 820575  | 26486   | 0.00514 |
| G x E     | 312572** | 1938233* | 43891** | 0.02946* |
| Residual  | 125132  | 971677  | 18790   | 0.01511 |

SOV: sources of variations, Gyield: grain yield per ha, Fyield: fodder yield per ha, Shyield: shell yield per ha, HI: harvest index.
and fodder yields. Superior genotypes were detected at Maradi and Kalapaté. Only one peak was observed in the density plots of both grain and fodder yields in each of the three sites. The peak of the density plot shows that the grain yield data are concentrated around 300 kg/ha at Tara, 1000 kg/ha at Kalapaté and 1800 kg/ha at Maradi. In terms of fodder yield, data concentration was observed around 800, 2400 and 5500 kg/ha at Tara, Kalapaté and Maradi, respectively.

According to the environment, the shell yield distribution follows the same trend as that of grain yield. A wide range was observed at Maradi and Kalapaté compared to Tara (Figure 4). The data concentration peaks were approximately at 100, 400 and 600 kg/ha at Tara, Kalapaté and Maradi in that order. However, considerable variations were observed in the harvest index at all the sites (Figure 4). Many peaks were observed in the density plot of Maradi, while Kalapaté has two peaks and only one for Tara. The harvest index data points were concentrated below 0.25 at Tara.
Tara. However, at Maradi and Kalapaté, the data concentration was between 0.25 and 0.5. Nevertheless, despite being the top regarding the power of distinguishing genotypes in terms of grain, fodder and shell yields, the site of Marado showed less variability with respect to harvest index than Kalapaté and Tara.

The overall mean grain yield was 962.8 kg/ha and ranged from 288.6 to 1198.3 kg/ha. Mean grain yield was 214.3 kg/ha at Tara, 1155.2 kg/ha at Kalapaté and 1518.9 kg/ha at Maradi (Table 3.). The best performing genotypes were IN15_62, IN17_142 and IN17_132 with yields of 1198.3, 1187.5 and 1122.9 kg/ha, respectively. These three top-yielding lines are the only ones that beat the check cultivar, TN5_78, which recorded a mean grain yield of 1103.8 kg/ha. The performance of the highest yielding line, IN15_62, as its mean grain yield varies significantly with the environment, which was a sign of its low yield stability. Large variation was observed in the performance of the highest yielding line, IN15_62, as its mean grain yield was 176.1, 1339.6 and 2079.2 kg/ha at Tara, Kalapaté and Maradi respectively. Among the top yielding cultivars, IN17_132 was the only one that seemed to have some level of stability with yield of 479.2 kg/ha at Tara, 1264.6 kg/ha at Maradi and 1625.0 kg/ha at Kalapaté. Other lines with high yielding potential include IN15_118 and IN17_28 with 1057.0 and 1056.6 kg respectively as mean grain yield per ha. IN17_03 which seedlings’ emergence was very poor turned out to be the less yielding genotype across the locations.

The overall mean fodder yield varied from 1263.0 to 3790.0 kg/ha. On the site basis, yield was 1060.0, 2662.0 and 5053.0 kg/ha at Tara, Kalapaté and Maradi respectively (Table 4.). The yield disparity was too significantly lower than that of best performing lines. The winning genotypes were IN17_142 with 3790.0 kg/ha, IN15_118 with 3670.0 kg/ha and IN17_132 with 3542.0 kg/ha. Different lines won in a different environments; however, the three top genotypes were among the top performing ones at Kalapaté and Maradi. The fodder yield of the check cultivar was significantly low compared to that of most newly developed lines. The lines such as IN17_142 and IN15_62 produced more than six tons of fodder yield at Maradi. Genotypes with high yield and relative stability were IN17_28 and IN17_10 with 3542.0 and 3384.0 kg/ha, respectively.

As expected, the best performing lines in terms of grain yield such as IN15_62 and IN17_142, also recorded the highest shell yield. Among the highest grain yielding genotypes, only IN17_132 did not record high shell yield. The mean shell yield ranges from 170.5 to 429.2 kg/ha (Table 5.). It varies with the environment as the yield of 82.2, 409.7 and 506.0 kg/ha were obtained at Tara, Kalapaté and Maradi. The mean shell yield of winning genotypes was 429.2 and 417.7 kg/ha for IN15_62 and IN17_142 respectively. The yield of the check cultivar, TN5_78, was 315.3 kg/ha which significantly lower than that of best performing lines. Different genotype won at different site as top yielding lines are IN17_03 (187.5 kg/ha) at Tara, IN15_118 (635.5 kg/ha) at Kalapaté and IN15_62 (685.4 kg/ha) at Maradi.

The mean harvest index ranges from 0.22 to 0.41 and the overall mean was 0.30 (data not shown) indicating that most the genotypes evaluated in the present study are dual purpose cultivars. None of the tested lines recorded a high mean harvest index. IN15_62 and IN17_142 which belong to high grain and fodder yielding genotypes recorded 0.30 and 0.31 mean harvest index. However, another top grain and fodder yielding lines, IN15_118 ended with a mean harvest index as low as 0.24.
Therefore, farmers who supplement these cultivars with good 
IN17_142 and IN15_62 at Maradi indicates their great yield potential. 
yields of over 2 and 6 tons respectively for grain and fodder recorded by 
the very poor performance at Tara which may be due to the soil very low 
stock farming. These lines have been able to record such yield despites 
try's farmers having access to irrigation and, combined crops and live-
stock farming. The dal-purpose genotypes such as IN17_142 and IN15_62, obtained above 1.2 and 3.5 tons 
thrived to produce high grain and fodder yields. The dal-purpose geno-
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 IN17.10 503.1 379.2 187.5 356.0
 IN17.28 392.7 613.5 57.3 354.5
 IN17.17 406.3 567.7 69.8 347.9
 IN17.132 510.4 397.9 126.0 344.8
 IN17.82 259.4 548.3 158.3 320.0
 TN5.78 300.0 604.2 41.7 315.3
 IN17.125 363.5 533.4 45.9 314.3
 IN17.77 327.1 366.7 57.3 250.4
 IN17.03 333.3 137.5 40.6 170.5
 Mean 409.7 506.0 82.2 332.7

| Genotype  | Kalapaté  | Maradi  | Tara  | Mean  |
|-----------|-----------|---------|-------|-------|
| IN15.62   | 410.4     | 793.8   | 83.4  | 429.2 |
| IN17.142  | 475.0     | 685.4   | 92.7  | 417.2 |
| IN15.118  | 635.5     | 444.8   | 26.1  | 368.8 |
| IN17.10   | 503.1     | 379.2   | 187.5 | 356.0 |
| IN17.28   | 392.7     | 613.5   | 57.3  | 354.5 |
| IN17.17   | 406.3     | 567.7   | 69.8  | 347.9 |
| IN17.132  | 510.4     | 397.9   | 126.0 | 344.8 |
| IN17.82   | 259.4     | 548.3   | 158.3 | 320.0 |
| TN5.78    | 300.0     | 604.2   | 41.7  | 315.3 |
| IN17.125  | 363.5     | 533.4   | 45.9  | 314.3 |
| IN17.77   | 327.1     | 366.7   | 57.3  | 250.4 |
| IN17.03   | 333.3     | 137.5   | 40.6  | 170.5 |
| Mean      | 409.7     | 506.0   | 82.2  | 332.7 |

IN17.28 and IN17.17 obtained the lowest harvest index of 0.11 at Tara 
while IN17.82 recorded the highest with 0.61 at the same environment. 

Figure 5 below displays the relationship between grain and fodder yields. It shows a high and positive correlation among the two traits as 
the grain yield increases with fodder. As a result, the highest grain 
yielding lines are the same that won also with respect to fodder, in other 
word a poor line in grain yield was also poor in fodder yield Therefore, 
there was no need to make selection for both grain and fodder yields at 
the same time, either of the traits can be used for selection of the other. 

4. Discussion

The hot dry season (march, april and may) in the Sahel agroecological 
zone of Niger is characterized by extremely high temperatures (Kiari et al., 2011) and low relative humidity. Despite these harsh climatic 
conditions, some cowpea lines evaluated in the present work have 
thrived to produce high grain and fodder yields. The dal-purpose geno-
types such as IN17_142 and IN15_62, obtained above 1.2 and 3.5 tons 
mean grain and fodder yields are a welcome development for the coun-
y's farmers having access to irrigation and, combined crops and live-
stock farming. These lines have been able to record such yield despites 
the very poor performance at Tara which may be due to the soil very low 
fertility as no fertilizer application was carried out. The very high mean 
yields of over 2 and 6 tons respectively for grain and fodder recorded by 
IN17_142 and IN15_62 at Maradi indicates their great yield potential. 
Therefore, farmers who supplement these cultivars with good 
agricultural practices may probably yield more than reported in the 
present work. Our results corroborate Souleymane et al. (2018) findings 
who reported cowpea lines with high grain and fodder yields under the 
dry season conditions in Niger. In addition, Kiari et al. (2011) evaluated 
cowpea varieties for seed and fodder production in Sahelian sandy soils of Niger and reported a mean grain yield of 1452 kg/ha. The authors 
claimed that this yield is by far greater than that obtained in the rainy 
season. Furthermore the study of Watanabe and Terao (1998) revealed 
three cowpea genotypes, TVu 11979, 11986 and 12348 with around 1 
t/ha grain yield during the dry season in the Sudan savannah of Nigeria. 
Also, Adewale (2021) reported that IT89KD-288 produced a grain yield 
of 3130.8 and 2833.5 kg/ha during the dry seasons of 2018 and 2019 
respectively when irrigated twice a day.

Cowpea shells are one of the most important feeds used by small 
holders in fattening small ruminants in Niger during the dry season. The 
highest shell yield recorded by the best performing lines in terms of grain 
yield is an indication that these two traits could be strongly and positively 
correlated. Similarly, the results of Kamai et al. (2014) showed the best 
performing genotypes concerning grain yield, except IT90K-277-2, were 
the ones that also recorded the highest shell weight per ha.

The study of Tchokanaka et al. (2016) in Zinder, a region in the south 
estern part of Niger, showed that the price of cowpea haulms is 2500F per 
bag of 22.5 kg while that of shells is 2.000F per bag de 16 kg. This 
indicates the high cost of these cowpea products especially compared to 
farmers’ low-income status. The impact of short supply on the price of 
these commodities in the dry season could negatively affect the revenues 
obtained from this business.

5. Conclusion

The results suggest that IN17_142, IN15_62 and IN17_132 are adapted 
to dry season cropping in Niger since they produced high grain and 
fodder yields. The registration of these lines and their subsequent 
adoption by farmers having access to irrigation facilities may increase 
cowpea production. Cowpea production in the dry season through 
appropriate varieties could make small scale farmers more resilient to 
climate change by improving their well-being and income since they use 
cowpea as food and an input in carrying out their small business such 
small ruminant fattening.

Declarations

Author contribution statement

Souleymane Abdou: Conceived and designed the experiments; Per-
formed the experiments; Analyzed and interpreted the data; Contributed 
reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

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