Original Research Article

Seasonal effects on the potential of three dual-purpose cowpeas varieties seeds and fodder production in Sahelian sandy soil of Niger

Abstract

In Niger, cowpea is primarily cultivated under rainfed conditions and therefore often suffers from water stress at the end of its cycle. However, cultivating dual-purpose varieties during the cold dry season can help minimize the effects of this stress and improve cowpea production. A field study was conducted to assess the seasonal effect (cold dry season and rainy season) on the yield of three dual-purpose cowpea varieties over two consecutive years, 2022 and 2023. The analysis of the results shows that pod and seed yields during the cold dry season were on average higher than those of the rainy season. The varieties can produce an average of over 4000 kg/ha of seeds during the cold dry season compared to 1770.18 kg/ha during the rainy season. During the rainy season, the varieties produced more haulms thanin the cold dry season, with 8217.38 kg/ha and 6163.19 kg/ha, respectively. During the cold dry season, cowpea benefited from low temperatures, which favored increased pod and seed yields. Due to its advantages, cowpea cultivation during the cold dry season should be developed and promoted in Niger.

Keywords: Cultural practice, yield, irrigation, season

1. Introduction

Cowpea is the main legume cultivated in Niger where it plays an important role in the diet. Its seeds are a source of protein for rural households [1] and its haulms, as crop residues, are also used for livestock feed, particularly during the dry seasons when forage availability is scarce [2]. It is one of the most important crops both in cropping systems and marketing channels after onions in Niger [3]. In addition to seeds, many cowpea varieties are cultivated for dual purposes, both for seeds and forage [4]. Studies on the practice and use of crop by-products in animal feed also indicate that cowpea residues are the most commonly used [5].

Cowpea is primarily cultivated during the rainy season, with yields ranging between 200 and 400 kg/ha [6]. Rainfall in Niger is unevenly distributed over time and space, exposing crops to end-of-cycle drought, often accompanied by high temperatures [7]. These drought episodes lead to yield losses in crops like cowpea, especially if they occur during critical stages such as flowering [8]. In addition to drought, other challenges include low soil fertility, parasitic plants such as striga, inappropriate varieties, and limited use of inputs [9]. The varieties commonly used by farmers are late-maturing and sensitive to photoperiod [10].

Given global changes, crops may experience temperature increases [11], which delay flowering [12] and consequently lead to yield reduction [13]. In addition to environmental factors, insects and other pests cause significant damage to cowpea, resulting in production losses [14]. Indeed, seeds harvested during the rainy season are often destroyed by insects during storage [15]. This raises the issue of seed availability, which becomes very costly, and consequently, farmers have no choice but to use cheap seeds of deficient quality [16]. Dual-purpose cowpea cropping systems in Niger, with additional cultivation of cowpea during the cold dry season under irrigation, can be a solution to the increasing demand for quality seeds and fodder [17].

The performance of dual-purpose varieties during the off-season in Niger has been extensively documented [7, 16,17, 18]. All these studies have shown that it is possible to produce dual-purpose cowpeas during the off-season, particularly with irrigation. However, none of these studies have evaluated the performance of dual-purpose cowpea varieties during the dry season and in rainfed conditions.

The objective of our work is to assess the seasonal effect on the performance of dual-purpose cowpea varieties between the cold dry season and the rainy season.

2. Materials and Methods

2.1.Experimental site

The experimentation was conducted in the field at the experimental site of the Faculty of Sciences and Techniques of Abdou Moumouni University of Niamey. This site is located between 13°30' North latitude and 2°05' East longitude, with an altitude of 204 meters. The soil is of tropical ferruginous lateritic type with a sandy texture. The average rainfall from 1992 to 2022 was 479.77 mm. The cumulative precipitation was 504.78 mm in 2021 and 436.70 mm in 2022.

Temperature was recorded daily using a thermo hygrometer (Tiny tag Ultra 2 TGU-4500 Gemini Data Loggers Ltd Chichester, UK) installed in the shade next to the experiment. The rainfall data was provided to us by the National Meteorological Service. Figure 1 shows the monthly distribution of precipitation and temperature for the two years 2021, and 2022.

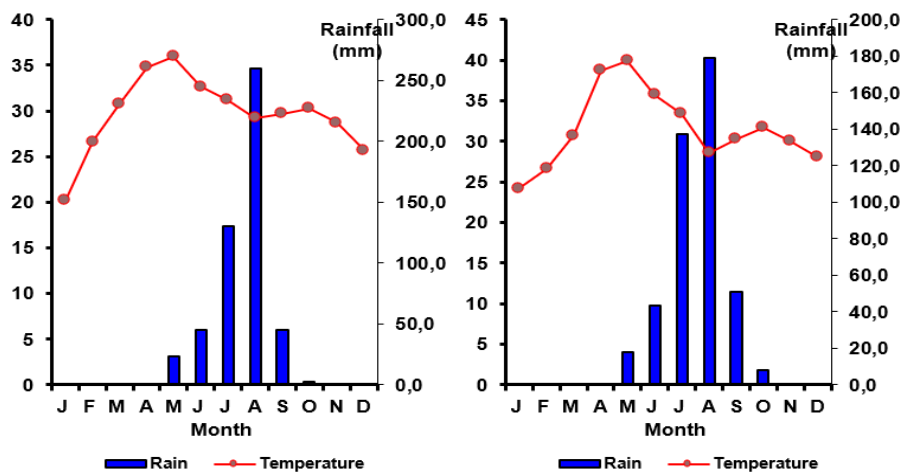


Figure 1: Monthly distribution of precipitation and temperature for the years 2021 and 2022 in Niamey

2.2.Experimental details

Three elite varieties of cowpea were used in this study, which are: CWS-F6-38-52 as V1, CWS-F6-38-36 as V2, and CWS-F6-38-34 as V3.

These varieties are derived from the selection program of the Cowpea Square Phase II project, led by the University of Maradi in Niger. These varieties have a 90-day cycle and are made available to producers for dual-purpose use, both as seeds and as fodder. The seeds are consumed but also represent an additional source of income for the producers, while the fodder is used for livestock feed. The trials were conducted for two consecutive years, with two trials conducted each year. For the first year, 2020-2021, the first trial was conducted from December 4, 2020, to March 1, 2021, under irrigation conditions; and the second trial under rainfed conditions from June 22, 2021, to October 10, 2021. For the second year, 2021-2022, the same dates were chosen for the irrigation conditions, and for rainfed cultivation, seeding occurred on June 19, 2022. The experimental design is a split plot with treatments (control and application of 200 kg/ha of NPK 15-15-15 fertilizer at sowing) in the main plots and cowpea varieties in subplots. Each main plot, with dimensions of 9.5 m × 9.2 m (87.4 m^2), was subdivided into 9 subplots (3 varieties × 3 replications). The elementary plots have an area of 6 m^2 (2.5 m × 2.4 m) and are spaced 1 m apart, while the main plots are spaced 2 m apart. Cowpea was sown at a rate of four seeds per hill with two plants per hill 15 days after sowing. The spacing between hills is 30 cm with a row spacing of 50 cm. A first weeding was done 15 days after sowing, followed by manual weeding to remove weeds. The soil was treated with furadan before sowing to prevent attacks from harmful fungi, nematodes, and bacteria affecting cowpea. The plants were treated twice with Titan insecticide at the vegetative stage to control insect attacks.

Daily monitoring was conducted to determine the phenological stages of the varieties, including the start date of flowering, 50% flowering date, start date of pod formation, and physiological maturity date of the pods. Harvesting took place as the pods reached physiological maturity, with continuous harvesting until the final harvest, where the biomass (stems + leaves) and cowpea pods were separated. After complete drying in the shade, yields of haulms, pods, and seeds were determined.

3. Data Analysis

After checking for normality using the Ryan-Joiner test and for equality of variance using Levene's test, with the aid of Minitab 16 software, an analysis of variance (ANOVA) was conducted using JMP 9.0 software. The generalized linear model was employed to assess the interaction among the different factors studied, including treatment (application or non-application of NPK), year, season, and variety.

4. Results

4.1. Inter-seasonal and annual variation and the influence of treatments on cowpea yields

The analysis of variance shows that all yield parameters as well as the start date of flowering were significantly affected by the season, year, and treatment. However, no significant differences were noted for the varieties (Table 1). In terms of year, the first year was more productive than the second year in terms of pods, seeds, and haulms, as well as in terms of the appearance of the first flowers. Pod, seed, and haulm yields were 5600 kg/ha, 4444.14 kg/ha, and 9391 kg/ha respectively in the first year, compared to 1784.18 kg/ha, 1358.26 kg/ha, and 4989.28 kg/ha respectively for pods, seeds, and haulms in the second year. Yields significantly decreased from the first year to the second year.The varieties used in this study yielded an average of over 4000 kg/ha during the off-season and 1770.18 kg/ha during the rainy season (Table 1). These yields are significantly higher than those obtained by [18] and [19], who obtained yields ranging from 962.8 kg/ha to 1452 kg/ha.Indeed, these two researchers worked from February to March, unlike our study, which took place from December to March.

At the seasonal level, the cold season appears to be more favorable for pod and seed production, with 5055.47 kg/ha during the cold season compared to 2329.16 kg/ha during the rainy season for pods, and 4032.22 kg/ha during the cold season compared to 1770.18 kg/ha during the rainy season for seeds. However, for haulm production, varieties significantly produce more haulms during the rainy season than during the cold dry season. The cold season also tends to shorten the flowering time of the varieties. At the treatment level, the application of NPK significantly increased pod, seed, and haulm yields and reduced the flowering time of the varieties.This work has shown that double-use cowpea can be significantly produced during the cold dry season in addition to the rainy season characterized by low yields. Cowpea cultivation during the dry cold season has resulted in higher yields of pods and seeds. However, varieties produce significantly more haulms and fewer seeds under rainy conditions. This low biomass production during the dry cold season is attributed to a shortened growth period resulting in early flowering (Table 1). Varieties tend to flower earlier during the cold season than during the rainy season. This reduction in the growth period after a certain threshold may hurt grain yield [19]. However, this does not seem to be the case in our study, with higher seed yields during the dry cold season. During the rainy season, weeds thrive around the experimental field due to heavy precipitation.

These weeds can serve as hosts to insects, whose damage can result in cowpea yield reduction of up to 20% [20].

Table 1: Variation in cowpea flowering date and yields among varieties, years, seasons, and treatments

Sources	Yield Parameters			
Variety	Days to flowering	Pod yield (Kg/ha)	Seed yield (Kg/ha)	Dry Biomass (Kg/ha)
V1	50,75±0,65A	2851,35±287,62A	2223,47±233,72A	7059,37±549,08A
V2	50,53±0,58A	2321,75±267,82A	1801,13±237,22A	7045,11±509,85A
V3	50,97±0,65A	2757,45±278,67A	2211,19±272,33A	7466,38±594,08A
Year				
Year 1	48,39±0,74B	3502,85±326,13A	2798,94±265,02A	9391,29±622,60A
Year 2	53,11±0,42A	1784,18±188,29B	1358,26±153,01B	4989,28±359,46B
Season				
Cold Dry Season	48,64±0,42B	5055,47±128,29A	4032,22±153,01A	6163,19±359,46B
Rainy Season	52,86±0,74A	231,56±32,16B	124,98±265,02B	8217,38±622,60A
Treatment				
NPK	50±0,55B	3103,57±243,08A	2431,62±197,53A	8481,9±464,06A
Control	51,51±0,55A	2183,46±208,86B	1725,58±197,53B	5898,68±464,06B
Variety	*0,74*	*0,146*	*0,123*	*0,34*
Year	*0,0001*	*0,014*	*0,010*	*0,0001*
Season	*0,0001*	*0,0001*	*0,0001*	*0,006*
Treatment	*0,035*	*0,02*	*0,02*	*0,0001*
Variety*Year	***0,018***	*0,19*	*0,33*	*0,85*
Variety*Season	*0,96*	*0,48*	*0,52*	***0,0008***
Variety*Treatment	*0,44*	*0,9*	*0,65*	*0,18*
Year*Season	***0,03***	***0,0001***	***0,0001***	***0,0001***
Year*Treatment	*0,14*	***0,0022***	***0,012***	*0,25*
Season*Treatment	*0,08*	***0,012***	***0,007***	***0,04***
Variety*Year*Season	*0,8*	*0,33*	*0,50*	*0,82*
Year*Season*Treatment	*0,72*	*0,18*	*0,14*	*0,46*
Variety*Season*Treatment	*0,82*	*0,98*	*0,67*	*0,15*
Variety*Year*Treatment	*0,61*	*0,91*	*0,54*	***0,017***
Variety*Year*Season*Treatment	*0,94*	*0,95*	*0,74*	***0,0084***

The numbers sharing the same letter(s) in the same column are not significantly different at the threshold of $p<0.05$.

4.2.Identifying the high-yield seasons for seeds and forage

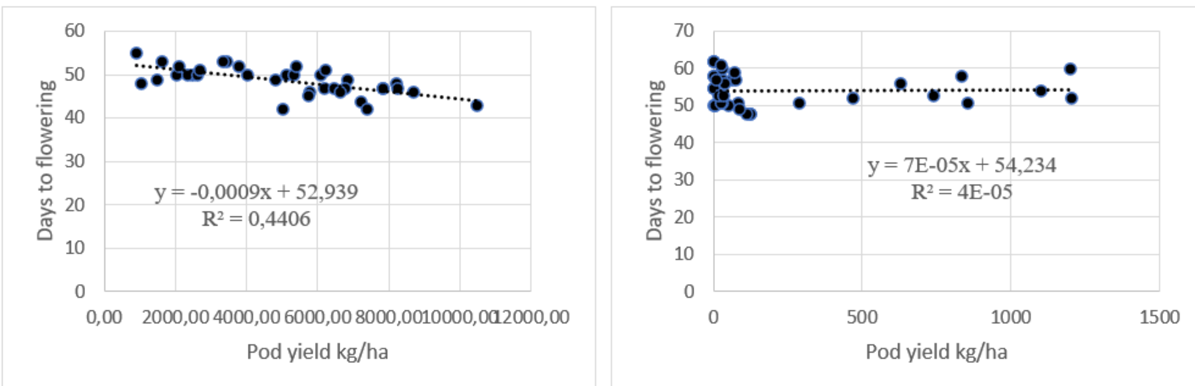
The analysis of interactions (Table 1) shows a significant interaction for the start of flowering between variety season *and year season* and a non-significant interaction between varietytreatment. This indicates that the effect of the year depends on the season and not on the variety, highlighting how the effect of the year on flowering is dependent on the season rather than the varieties. The cold season, favorable for flowering, tends to shorten the flowering time in the studied varieties. This period coincides with shorter daylight hours, during which varieties can take advantage of lower nighttime temperatures to flower and produce significantly more pods. [21] Mutters and Hall (1992) reported that on short days, lower nighttime temperatures tend to favor higher pod production in cowpea compared to high temperatures.

For pod and seed yields, the interactions between year treatment *and season treatment* are significant, while the interaction between variety and treatment is not significant. This indicates that the effect of the year changes depending on the treatment on one hand, and the effect of treatment changes depending on the season on the other hand. The varieties produce significantly more pods and seeds and fewer haulms during the cold season, and the application of NPK does not explain the performance of the studied varieties.

For haulm yield, the interactions between variety*year*season*treatment are significant, indicating that the effect of year changes depending on the season and the effect of treatment changes depending on the season as well. Indeed, haulm production during the cold dry season is not influenced by the treatment, but rather during the rainy season where yields are higher with the application of NPK compared to the controls.

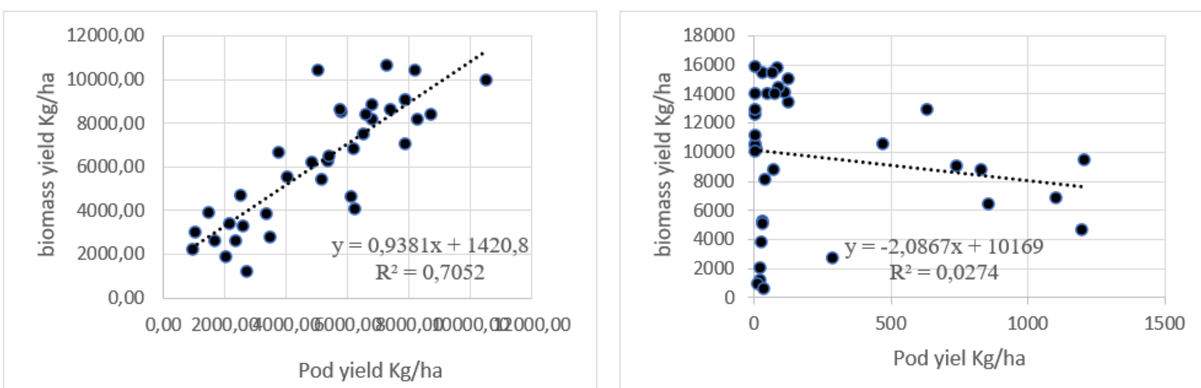
The relationship between the start date of flowering in varieties and pod yield shows a highly significant negative correlation (R2 = 0.44, P = 0.0001) during the cold dry season and a non-significant correlation during the rainy season (Figure 1). When sown during the cold dry season, the start date of flowering was earlier compared to sowing during the rainy season. As the start date of flowering decreases, pod and seed yields increase.During the dry cold season,they were allowed for the shortening of the cowpea cycle, leading to good pod production. Similar results were reported by [22], where a negative correlation was obtained between maturity date and cowpea seed yield. During the dry cold season, the varieties were cultivated under irrigation and did not suffer from any drought stress, unlike during the rainy season where the varieties may experience end-of-cycle droughts that can lead to yield reduction.

Furthermore, the relationship between biomass yield and pod yield shows a highly significant positive correlation during the dry season (R2 = 0.84, P = 0.0001) and a non-significant negative correlation during the rainy season (Figure 2).



(A) Dry season (B) Rainy season

Figure2: Days to a flowering relationship with pod yield



(A) Dry season (B) Rainy season

Figure 3: Biomass yield relationship with pod yield

5. Discussion

This work has shown that double-use cowpea can be significantly produced during the cold dry season in addition to the rainy season characterized by low yields. Cowpea cultivation during the dry cold season has resulted in higher yields of pods and seeds. However, varieties produce significantly more haulms and fewer seeds under rainy conditions. This low biomass production during the dry cold season is attributed to a shortened growth period resulting in early flowering (Table 1). Varieties tend to flower earlier during the cold season than during the rainy season. This reduction in the growth period after a certain threshold may hurt grain yield [19]. However, this does not seem to be the case in our study, with higher seed yields during the dry cold season. During the rainy season, weeds thrive around the experimental field due to heavy precipitation. These weeds can serve as hosts to insects, whose damage can result in cowpea yield reduction of up to 20% [20].

The varieties used in this study yielded an average of over 4000 kg/ha during the off-season and 1770.18 kg/ha during the rainy season (Table 1). These yields are significantly higher than those obtained by [18] and [19], who obtained yields ranging from 962.8 kg/ha to 1452 kg/ha. Indeed, these two researchers worked from February to March, unlike our study, which took place from December to March. This period coincides with shorter daylight hours, during which varieties can take advantage of lower nighttime temperatures to flower and produce significantly more pods. [21] Mutters and Hall (1992) reported that on short days, lower nighttime temperatures tend to favor higher pod production in cowpea compared to high temperatures. The relationship between the start date of flowering and pod yield showed a highly significant negative correlation (figure). The dry cold season they were allowed for the shortening of the cowpea cycle, leading to good pod production. Similar results were reported by [22], where a negative correlation was obtained between maturity date and cowpea seed yield. During the dry cold season, the varieties were cultivated under irrigation and did not suffer from any drought stress, unlike during the rainy season where the varieties may experience end-of-cycle droughts that can lead to yield reduction. This additional production during the off-season can help compensate for the problem of seed availability, which becomes expensive during the next rain-dependent agricultural season.

6. Conclusion

We evaluated the production potential of four dual-purpose cowpea varieties during the dry cold season and the rainy season. End-of-cycle droughts and high temperatures during the reproductive period are significant challenges that need to be addressed to boost the production of this economic and food security important crop. Cowpea productivity can be enhanced by incorporating off-season cultivation during the dry cold season of dual-purpose varieties, which can supplement production in rain-dependent conditions. Additionally, the cold season coincides with low temperatures and short photoperiods favorable for cowpea production. This season may contribute to shortening the cowpea development cycle through early flowering and improving pod and seed yields.

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