

1 **Original Research Article**

2 **Seasonal effects on performance of three dual-purpose cowpeas varieties production in Sahelian**
3 **sandy soil of Niger**

4

5 **Abstract**

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

18 **Keywords:** Cultural practice, yield, irrigation, season

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27 **1. Introduction**

28 Cowpea is the main legume cultivated in Niger where it plays an important role in the diet. Its
29 seeds are a source of protein for rural households [1] and its haulms, as crop residues, are also

30 used for livestock feed, particularly during the dry seasons when forage availability is scarce [2].
31 It is one of the most important crops both in cropping systems and marketing channels after
32 onions in Niger [3]. In addition to seeds, many cowpea varieties are cultivated for dual purposes,
33 both for seeds and forage [4]. Studies on the practice and use of crop by-products in animal feed
34 also indicate that cowpea residues are the most commonly used [5].

35 Cowpea is primarily cultivated during the rainy season, with yields ranging between 200 and 400
36 kg/ha [6]. Rainfall in Niger is unevenly distributed over time and space, exposing crops to end-
37 of-cycle drought, often accompanied by high temperatures [7]. These drought episodes lead to
38 yield losses in crops like cowpea, especially if they occur during critical stages such as flowering
39 [8]. In addition to drought, other challenges include low soil fertility, parasitic plants such as
40 striga, inappropriate varieties, and limited use of inputs [9]. The varieties commonly used by
41 farmers are late-maturing and sensitive to photoperiod [10].

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

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

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

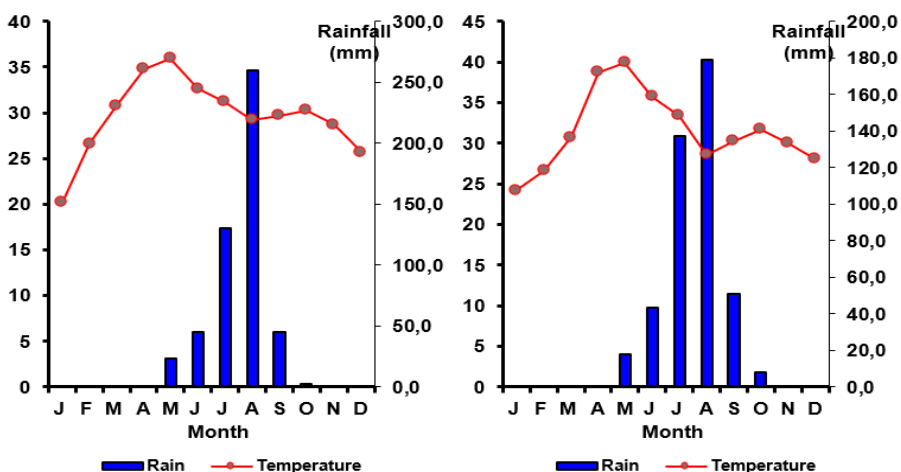
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58 **2. Materials and Methods**

59 2.1.Experimental site

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

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



69
70 Figure 1: Monthly distribution of precipitation and temperature for the years 2021 and 2022 in Niamey

72 2.2.Experimental details

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

75 These varieties are derived from the selection program of the Cowpea Square Phase II project,
76 led by the University of Maradi in Niger. These varieties have a 90-day cycle and are made
77 available to producers for dual-purpose use, both as seeds and as fodder. The seeds are consumed
78 but also represent an additional source of income for the producers, while the fodder is used for
79 livestock feed. The trials were conducted for two consecutive years, with two trials conducted

80 each year. For the first year, 2020-2021, the first trial was conducted from December 4, 2020, to
81 March 1, 2021, under irrigation conditions; and the second trial under rainfed conditions from
82 June 22, 2021, to October 10, 2021. For the second year, 2021-2022, the same dates were chosen
83 for the irrigation conditions, and for rainfed cultivation, seeding occurred on June 19, 2022. The
84 experimental design is a split plot with two factors, treatments (control and application of 200
85 kg/ha of NPK 15-15-15 fertilizer at sowing) in the main plots and cowpea varieties in subplots.
86 Each main plot, with dimensions of 9.5 m × 9.2 m (87.4 m²), was subdivided into 9 subplots (3
87 varieties × 3 replications). The elementary plots have an area of 6 m² (2.5 m × 2.4 m) and are
88 spaced 1 m apart, while the main plots are spaced 2 m apart. Cowpea was sown at a rate of four
89 seeds per hill with two plants per hill 15 days after sowing. The spacing between hills is 30 cm
90 with a row spacing of 50 cm. A first weeding was done 15 days after sowing, followed by manual
91 weeding to remove weeds. The soil was treated with furadan before sowing to prevent attacks
92 from harmful fungi, nematodes, and bacteria affecting cowpea. The plants were treated twice
93 with Titan insecticide at the vegetative stage to control insect attacks.

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

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102 **3. Data Analysis**

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

108

109 **4. Results**

110 **4.1. Inter-seasonal and annual variation and the influence of treatments on cowpea**
111 **yields**

112 The analysis of variance shows that all yield parameters as well as the start date of flowering
113 were significantly affected by the season, year, and treatment. However, no significant
114 differences were noted for the varieties (Table 1). In terms of year, the first year was more
115 productive than the second year in terms of pods, seeds, and haulms, as well as in terms of the
116 appearance of the first flowers. Pod, seed, and haulm yields were 5600 kg/ha, 4444.14 kg/ha, and
117 9391 kg/ha respectively in the first year, compared to 1784.18 kg/ha, 1358.26 kg/ha, and 4989.28
118 kg/ha respectively for pods, seeds, and haulms in the second year. Yields significantly decreased
119 from the first year to the second year. The varieties used in this study yielded an average of over
120 4000 kg/ha during the off-season and 1770.18 kg/ha during the rainy season (Table 1). These
121 yields are significantly higher than those obtained by [18] and [19], who obtained yields ranging
122 from 962.8 kg/ha to 1452 kg/ha. Indeed, these two researchers worked from February to March,
123 unlike our study, which took place from December to March.

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

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

142

143 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±287,6 2A	2223,47±233,72 A	7059,37±549,08A
V2	50,53±0,58A	2321,75±267,8 2A	1801,13±237,22 A	7045,11±509,85A
V3	50,97±0,65A	2757,45±278,6 7A	2211,19±272,33 A	7466,38±594,08A
Year				
Year 1	48,39±0,74B	3502,85±326,1 3A	2798,94±265,02 A	9391,29±622,60A
Year 2	53,11±0,42A	1784,18±188,2 9B	1358,26±153,01 B	4989,28±359,46B
Season				
Cold Dry Season	48,64±0,42B	5055,47±128,2 9A	4032,22±153,01 A	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±243,0 8A	2431,62±197,53 A	8481,9±464,06A
Control	51,51±0,55A	2183,46±208,8 6B	1725,58±197,53 B	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

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

146

147 **4.2. Identifying the high-yield seasons for seeds and forage**

148 The analysis of interactions (Table 1) shows a significant interaction for the start of flowering
149 between variety season *and year season* and a non-significant interaction between variety
150 treatment. This indicates that the effect of the year depends on the season and not on the variety,
151 highlighting how the effect of the year on flowering is dependent on the season rather than the
152 varieties. The cold season, favorable for flowering, tends to shorten the flowering time in the
153 studied varieties. This period coincides with shorter daylight hours, during which varieties can
154 take advantage of lower nighttime temperatures to flower and produce significantly more pods.
155 [21] Mutters and Hall (1992) reported that on short days, lower nighttime temperatures tend to
156 favor higher pod production in cowpea compared to high temperatures.

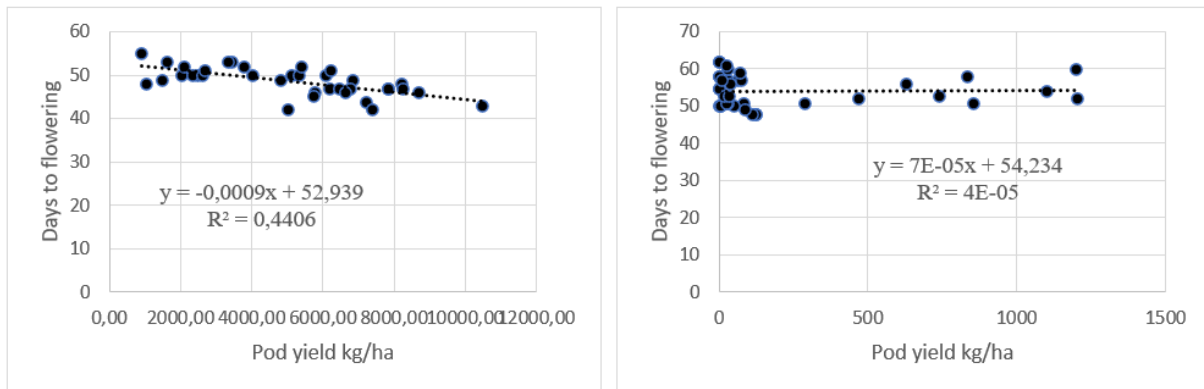
157 For pod and seed yields, the interactions between year treatment *and season treatment* are
158 significant, while the interaction between variety and treatment is not significant. This indicates
159 that the effect of the year changes depending on the treatment on one hand, and the effect of
160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

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

168 The relationship between the start date of flowering in varieties and pod yield shows a highly
169 significant negative correlation ($R^2 = 0.44$, $P = 0.0001$) during the cold dry season and a non-
170 significant correlation during the rainy season (Figure 1). When sown during the cold dry season,
171 the start date of flowering was earlier compared to sowing during the rainy season. As the start
172 date of flowering decreases, pod and seed yields increase. During the dry cold season, they were
173 allowed for the shortening of the cowpea cycle, leading to good pod production. Similar results
174 were reported by [22], where a negative correlation was obtained between maturity date and

175 cowpea seed yield. During the dry cold season, the varieties were cultivated under irrigation and
 176 did not suffer from any drought stress, unlike during the rainy season where the varieties may
 177 experience end-of-cycle droughts that can lead to yield reduction.

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

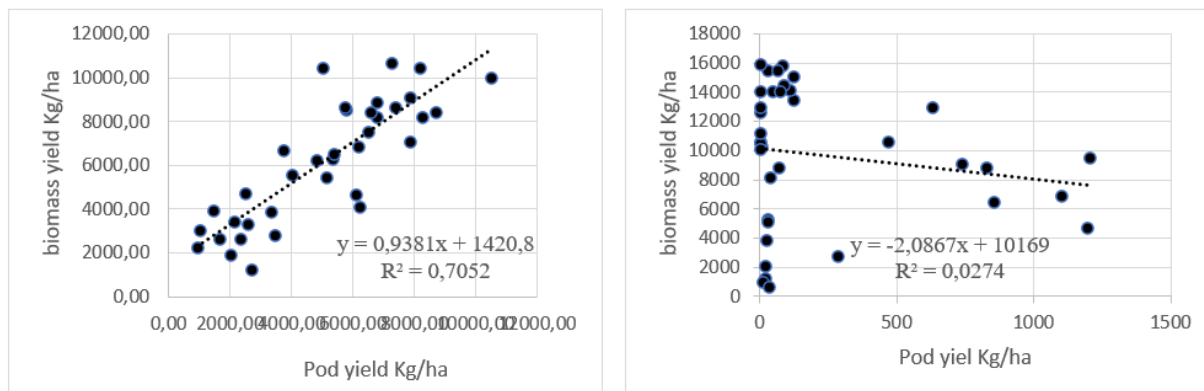


(A) Dry season

(B) Rainy season

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182 Figure2: Days to a flowering relationship with pod yield



(A) Dry season

(B) Rainy season

183

184 Figure 3: Biomass yield relationship with pod yield

185

186 5. Discussion

187 This work has shown that double-use cowpea can be significantly produced during the cold dry
 188 season in addition to the rainy season characterized by low yields. Cowpea cultivation during the
 189 dry cold season has resulted in higher yields of pods and seeds. However, varieties produce

190 significantly more haulms and fewer seeds under rainy conditions. This low biomass production
191 during the dry cold season is attributed to a shortened growth period resulting in early flowering
192 (Table 1). Varieties tend to flower earlier during the cold season than during the rainy season.
193 This reduction in the growth period after a certain threshold may hurt grain yield [19]. However,
194 this does not seem to be the case in our study, with higher seed yields during the dry cold season.
195 During the rainy season, weeds thrive around the experimental field due to heavy precipitation.
196 These weeds can serve as hosts to insects, whose damage can result in cowpea yield reduction of
197 up to 20% [20].

198 The varieties used in this study yielded an average of over 4000 kg/ha during the off-season and
199 1770.18 kg/ha during the rainy season (Table 1). These yields are significantly higher than those
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202 December to March. This period coincides with shorter daylight hours, during which varieties
203 can take advantage of lower nighttime temperatures to flower and produce significantly more
204 pods. [21] Mutters and Hall (1992) reported that on short days, lower nighttime temperatures tend
205 to favor higher pod production in cowpea compared to high temperatures. The relationship
206 between the start date of flowering and pod yield showed a highly significant negative correlation
207 (figure). The dry cold season they were allowed for the shortening of the cowpea cycle, leading
208 to good pod production. Similar results were reported by [22], where a negative correlation was
209 obtained between maturity date and cowpea seed yield. During the dry cold season, the varieties
210 were cultivated under irrigation and did not suffer from any drought stress, unlike during the
211 rainy season where the varieties may experience end-of-cycle droughts that can lead to yield
212 reduction. This additional production during the off-season can help compensate for the problem
213 of seed availability, which becomes expensive during the next rain-dependent agricultural season.

214

215 **6. Conclusion**

216 We evaluated the production potential of four dual-purpose cowpea varieties during the dry cold
217 season and the rainy season. End-of-cycle droughts and high temperatures during the
218 reproductive period are significant challenges that need to be addressed to boost the production of
219 this economic and food security important crop. Cowpea productivity can be enhanced by

220 incorporating off-season cultivation during the dry cold season of dual-purpose varieties, which
221 can supplement production in rain-dependent conditions. Additionally, the cold season coincides
222 with low temperatures and short photoperiods favorable for cowpea production. This season may
223 contribute to shortening the cowpea development cycle through early flowering and improving
224 pod and seed yields.

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UNDER PEER REVIEW