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Upland Rice and Dry Season Sorghum Production under Double Cropping Systems in a Tropical Semi-Arid Region

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Authors' contributions

This work was carried out in collaboration between all authors. Author JPMA designed the study, wrote the protocol, performed the statistical analysis and wrote the first draft of the manuscript. Author AB supervised the field work and data collection. Author HBD managed the literature searches and edited the final document. All three authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: To investigate the influence of upland rice cultivar and dry season sorghum planting date on crop yield under rainfed double cropping systems as an option to increase cereal production for food security and income generation to farmers.
Study Design: The experimental design was a randomized complete block design with 20 replicates for rice cultivars evaluation the first year (2009). Part of the experimental set up was subsequently used the following year (2010) to evaluate dry season sorghum production as second crop in the system. Treatments were the nine combinations of previous rice cultivars and sorghum transplanting dates replicated four times.
Place and Duration of Study: Experiments were conducted in 2009 and 2010 in a tropical semi-arid area, at Salak in the outskirts of Maroua, the main city of the Far-Northern Region of Cameroon.
Methodology: The three rice cultivars of Brazilian origin tested in this experiment were B22, Primavera and SEBOTA 281.2. They were followed by the local sorghum variety called "Guelendeng'', sown at three different dates at the onset of dry seasons. Factors

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evaluated were the paddy yields of rice cultivars and grain yield of dry season sorghum.
Results: The rice cultivars were able to grow and score paddy yields ranging between 2.6 and 5.2tha^{-1}, with a highly significant interaction between years and cultivars (P<0.001). Upland rice grown in the rainy season was followed by the production of 832 to 1819 kg ha^{-1} of dry season grain sorghum depending on year or preceding rice cultivar. Planting date did not reveal a significant effect on dry season sorghum yield but the latter was significantly determined by preceding rice cultivar P<0.001). Dry season sorghum yield was significantly higher, when the preceding rice cultivar was Primavera the rainiest year (2010), or significantly lower the driest year (2009).
Conclusion: The choice of an upland rice cultivar to be included in double cropping systems with dry season sorghum is important but questions remain concerning the sustainability of the system in relation to moisture and nutrient management. Designing adequate fertilization schemes for cereals in double cropping systems and the availability of relevant short cycle upland rice cultivars to be included as dry season sorghum preceding crop are main challenges to be addressed.

Keywords: Cropping systems; double cropping; upland rainfed rice; dry season sorghum; transplanted sorghum; vertisols; food security.

1. INTRODUCTION

Efforts to increase national cereal production in Cameroon have led to the investigation on double cropping systems of rice and dry season sorghum (*Sorghum bicolor* (Linn.) Moench), on vertisols in the Far-Northern Region of the country [1,2]. Sorghum, rice and other cereals are staple foods for local people but their supply is inadequate due to low yields or frequent crop failure [3,4]. Also, local people cannot afford purchasing cereals from the market due to poverty and limited income. Consequently, famine and malnutrition often plague in the region [5]. Dry season sorghum locally called ''Muskwari'', is a reliable back-up against the failure of rainfed sorghum [6,7]. About 46% of households cultivate dry season sorghum as sole crop on farms averaging 1.4ha [8].

Dry season sorghum is transplanted on heavy-clayed vertisols at the beginning of the dry season and is capable to uptake residual water from non tilled soils to complete its cycle [2,9]. The potential of vertisols for rice production is high and they are regarded as soils where rice can be introduced, without using the land reserved for other food crops [1,4]. Vertisols characteristically swell, become sticky and impermeable when wet. As a result, large land tracks of vertisols in the Far-Northern Region of Cameroon are left flooded and abandoned during rainy season.

Introducing rice in the rainy season on wet or inundated vertisols before planting dry season sorghum may be a good strategy to increase domestic rice production and reduce rice imports. The latter have been on the rise in recent years and they exceeded 500 000 [10]. About 95% of the population eats rice at least once a week in Cameroon [3], but little has been undertaken to improve domestic production. National rice production was estimated at 65 000 tons over a cultivated area ca. 50 000 ha [10]. Rice is mainly produced under irrigation (87%) and rainfed lowland (9%); the rest (4%) is cultivated under upland conditions where the sole water supply is rainwater [10]. Farmers are becoming more and more interested in upland rice production due to the availability of improved early maturing cultivars. Some 30 cultivars of that type have been supplied for trial in various ecosystems in the Far-Northern Region of Cameroon between 2000 and 2004 [11,12].

The period within which dry season sorghum can be successfully transplanted at the onset of the dry season is short and is determined empirically by farmers based on the pattern of late rains [4,13]. This practice is well established in Northern Cameroon since the 19th century [14] and has assisted greatly to food security [4,9]. However, dry season sorghum as second crop may be affected by preceding rice variety or by relative late plantings on drying vertisols.

Vertisols cover more than 800 000 ha in the Far-Northern Region of Cameroon alone [15] and more than 50% are suitable for upland rice production [13]. However, properties of vertisols vary depending on their location on the landscape. In lowland position, they are inundated for periods varying from days to weeks. In upland position, inundations barely exceed a few hours or days. Double cropping of rice and dry season sorghum was examined under rainfed lowland conditions [1,2]. Such investigations are needed in other ecosystems including upland situations. It is useful to investigate farming systems that could benefit farmers both for food security and income generation. A system that would jeopardize dry season sorghum systems may not be accepted by local farmers [7]. This paper examines the possibility of growing rice and sorghum in double culture cropping systems on upland vertisols in a semi-arid tropical region of Cameroon.

2. MATERIALS AND METHOD

2.1 Experimental Site

Experiments were conducted in 2009 and 2010 in a tropical semi-arid area named Salak in the outskirts of Maroua, the main city of the Far-Northern Region of Cameroon. The site is a flat upland traditionally used for dry season sorghum production exclusively. Monthly precipitations records from the local meteorological station, and soil characteristics determined by routine laboratory methods [16] are indicated in Table 1 and Table 2, respectively.

2.2 Crop Varieties

The three rice cultivars of Brazilian origin tested in this experiment were B22, Primavera and SEBOTA 281.2 whose summary descriptions are given in Table 3 [11]. They were selected based on their adaptation to rainfed conditions [17]. They need less than 120 days to be harvested. The sorghum variety under investigation is ''Guelendeng''. The main distinctive feature of this local variety is its short cycle and suitability for late plantings.

Table 1. Monthly precipitations (in mm) over the experimental site at Salak in 2009 and 2010

Year	J	F	M	A	M	J	J	A	S	O	N	D	Total
2009	0	0	0	24	35	57	186	199	96	0	0	0	597
2010	0	0	0	14	61	93	227	248	94	88	0	0	825

Source: [17]

Table 2. Properties of the topsoil (0-20cm) of the experimental site as determined by routine laboratory methods

Particulars	Value	Methods
Sand (%)	22	Pipette Method
Silt (%)	48	Pipette Method
Clay (%)	30	Pipette Method
pH (1:2.5::Soil:Water)	6.24	Glass Electrode, pH Meter
Organic carbon (%)	1.78	Walkley and Black
Total N (g kg^{-1})	1.76	Modified Kjeldahl Method
CEC (meq $100g^{-1}$ of soil)	4.54	Ammonium acetate at pH 7
Available Phosphorus ($mgkg^{-1}$)	53	Bray II

Table 3. Characteristics of the three rice cultivars of Brazilian origin (SEBORA 281.2, B22 and Primavera) used in the experiment

Rice cultivars	Plant Characteristics	
	Aptitude	Length of growing cycle (days)
SEBOTA 281.2	Upland, lowland or irrigated	115-120
B22	Upland	105-110
Primavera	Upland	105-110

Source: [11]

2.3 Treatments and Experimental Design

Treatments were the nine combinations of the three rice cultivars and the three dry season sorghum transplanting dates replicated four times. The experimental design was a randomized complete block design with 20 replicates for rice cultivars evaluation the first year (2009). Part of the experimental setup was subsequently used the subsequent year (2010) to evaluate dry season sorghum production as second crop in the system. Experimental units were 5m by 8m plot of land. Spacing was 1.5m between blocs and 1m between adjacent experimental units. Factors evaluated were the paddy yields of the three rice cultivars and grain yield of the dry season sorghum subsequently transplanted at three different dates.

2.4 Cropping Practices

A non-selective herbicide (Glyphosate) was applied over the experimental units before planting. Rice was seeded on July 2nd in 2009 and on June 29th in 2010 at 20cm by 20cm. After each band of four rice lines, a space of 40cm wide was provided for relay planting of sorghum later in the season.

Rice seeds were directly hand planted on non tilled vertisols after their cracks were closed following the first rains. Holes of 5 cm depth were opened using a sharp stick and 5 rice seeds were dropped into planting holes. Then, 15 days after emergence, $150kgha^{-1}$ of urea were applied on rice experimental units. This was followed 30 days later by the application of $200kgha^{-1}$ of NPK fertilizer 22-10-15 as locally recommended. Rice plots were hand weeded twice during the growing season. After rice harvest, sorghum was transplanted at 1m by 1m in experimental units. In 2009, sorghum nurseries were planted on August 24th and 30th. In 2010, the planting dates of nurseries were August 25^{th} and September

1st. Sorghum was transplanted on November 6th, 12th and 18th in 2009 and September 30th, October 10th and October 20th in 2010. No fertilizer was applied to dry season sorghum and its weeding was not necessary.

2.5 Data Collection and Analysis

Rice yields were estimated from 1m^2 subplots at the centre of experimental units while sorghum yields were obtained from the two central lines. Yields from experimental units were translated to amounts per hectare and analyzed. The grain humidity of rice varieties was near 8%. Data were introduced on Excel sheets, and then transferred to Statistical Analysis System (SAS) software analysis. Procedures GLM and MEANS of SAS aided to perform the analysis of variance and the means' comparison. The probability level was 5% for significant differences and 1% for highly significant differences.

3. RESULTS AND DISCUSSION

3.1 Paddy Rice Production

Rice was the first crop in the system and all three cultivars under study were able to grow and provide a yield on upland vertisols. Paddy rice yields were between 2.6 and 5.2tha^{-1} Table 4. The analysis of variance indicates a highly significant interaction between years and cultivars for rice production Table 5. The rice cultivar SEBOTA 281.2 scored higher yield of paddy than Primavera and B22 in overall. In 2009 the driest year, Primavera produced more paddy than B22 but in 2010 under wetter conditions, the opposite trend was observed Table 4.

Table 4. Mean rice paddy yields in kg ha^{-1} of the three rice cultivars SEBOTA 281.2, Primavera and B22 obtained in 2009 and 2010

Years (Y)	Rice cultivars (R)	Rice paddy yield (kg ha^{-1})	
		Mean	Standard Error
2009	SEBOTA 281.2	4201	163
	Primavera	3776	188
	B22	2653	108
2010	SEBOTA 281.2	5204	131
	Primavera	3701	125
	B22	3921	109

Table 5. Summary of analysis of variance of data from paddy production of three rice cultivars B22, Primavera and SEBOTA 281-2 obtained in 2009 and 2010 on upland Vertisols at Salak in the Far North Region of Cameroon

Sources of variation	DF	Mean Square	F value	Pr>F
Bloc	19	3032329	2.81	0.0001**
Year	1	48246854	44.65	<.0001**
Rice cultivar	2	62720413	58.04	<.0001**
Year*Rice cultivar	2	15200062	14.07	<.0001**

***: Significant at the 1% level*

Yields obtained Table 4. are in the range of the 2 to 6tha^{-1} harvested by local farmers when they grow rice alone under lowland conditions [4]. However, yields observed in this experiment were low as compared to those obtained with the same varieties under more favorable conditions. SEBOTA 281.2 produced more than 10tha^{-1} of paddy rice in the Lake Alaotra area in Madagascar where rainfall is 1000 to 1200mm over 06 months [11]. In general, yields were better in 2010 compared to 2009 due to improved moisture conditions. On the experimental site, rainfall was 597 mm and 825mm in 2009 and 2010, respectively. It is noteworthy to observe that prevailing climatic conditions were not conducive to achieving the full potential of tested varieties Table 3.

Although all three rice varieties are considered suitable for upland rainfed conditions, it appears that when moisture conditions are better, B22 produces more paddy than Primavera and yields of SEBOTA 281.2 increase at a greater magnitude. SEBOTA 281.2 cultivar with a longer cycle (115 to 120 days) can be grown under rainfed or irrigated conditions [11]. In a similar experiment on lowland vertisols in another locality and in combination with other varieties, SEBOTA 281.2 produced up to 7.6tha^{-1} of paddy rice [1]. Primavera is a strict upland rice cultivar which is very sensitive to water-saturated soils. This is probably why it yielded less than B22 under wetter conditions in 2010. They roughly have the same cycle (105 to 110 days). The cultivar B22 is also upland but more tolerant to soil water saturation than Primavera. B22 took advantage of the late rains that occurred in October 2010 (88 mm). The behavior of the two rice cultivars differs depending on growing conditions. This suggests that the amount of rainfall and availability of soil moisture are determinant factors for the choice of upland rice varieties, especially in areas with relatively short growing seasons as it is the case in the semi-arid area of the Far-Northern Region of Cameroon.

The shrinkage of the rainy season in the semi-arid area of the Far-Northern Region of Cameroon was documented from compiled records of the beginnings and ends of successive rainy seasons since 1940 [18]. There is a need for crops and cultivars with short growing cycles. These can be found among the SEBOTA [11] and NERICA [12] rice cultivars. The cultivar SEBOTA 281.2 performed well in both years. The choice of rice cultivar has a significant impact on both individual crop yield and the system yield, when overall grain production is considered. Moreover, cultural practices that prolong rice cycle should be avoided. Application of nitrogen in excessive dosage often delay rice maturity [19] and would delay the planting of dry season sorghum. However, low rates of fertilizer application would jeopardize the sustainability of the double cropping system. Both rice and dry season sorghum need large amounts of nitrogen depending on crop yield [20].

3.2 Dry Season Sorghum Production after Rice

Dry season sorghum was the second crop in the double cropping system. Average dry season sorghum yields varied from 832 to 1819kgha^{-1} depending on year and preceding rice cultivar Table 6. The analysis of variance revealed highly significant effects of year and preceding rice cultivar on the production of dry season sorghum Table 7. The average yield of sorghum was 1537kgha^{-1} in 2009 and 920kgha^{-1} in 2010. With regard to the preceding rice cultivar, dry season sorghum yield was higher (1094kgha^{-1}) when the preceding rice cultivar was Primavera the rainiest year (2010) and lower (1145kgha^{-1}) with B22 as preceding rice cultivar in 2009, the driest year Table 6.

Producing rice in the rainy season did not prevent cultivation of subsequent dry season sorghum on upland vertisols. After paddy rice harvest, it was possible to grow a sorghum crop on upland vertisols successfully. Subsequent dry season sorghum grain yields ranged between 832 and 1819kgha^{-1} within the two years of observation. Dry season sorghum yields obtained under upland conditions are more important compared to the 540 to 811kgha^{-1} harvested after rice under lowland conditions [1]. In general, sorghum production as second crop was better on the upland site compared to the lowland location where plantings had to be delayed due to excess soil moisture and late rice harvest. On the upland site, early sowing was achieved by relay plantings of dry season sorghum. Farmers' dry season sorghum yields in sole cropping systems vary from 0 to more than 3tha^{-1} in Northern Cameroon, depending on soil and climatic conditions. Reported mean yields of dry season sorghum grown as sole crop under experimental conditions varied from 500 to 1500kgha^{-1} [13].

Table 6. Mean dry season sorghum yield of the local variety ''Gueleldeng'' grown after rice cultivars in 2009 and 2010 on Vertisols on the experimental site at Salak in the semi-arid area of the Far North Region of Cameroon

Year (Y)	Preceding rice cultivar (R)	Dry season sorghum yield (kg ha^{-1})	
		Mean	Standard Error
2009	SEBOTA 281.2	1819	248
	B22	1145	98
	Primavera	1646	175
2010	SEBOTA 281.2	834	73
	B22	832	58
	Primavera	1094	81

Table 7. Summary of the analysis of variance of yield data of the local dry season sorghum cultivar ''Gueleldeng'' after three rice cultivars B22, Primavera and SEBOTA 281.2 in 2009 and 2010 on upland Vertisols at Salak in the Far North Region of Cameroon

Sources of variation	Df	Mean Square	F value	Pr > F
Replicate	3	431685	2.89	0.04*
Year	1	2386384	15.99	0.0002**
Preceding rice cultivar	2	1081674	7.25	0.0017**
Planting date	2	291782	1.95	0.15
Year * Preceding rice cultivar	2	66773	0.45	0.64
Year * Planting date	2	78201	0.52	0.59
Preceding rice cultivar * Planting date	4	265158	1.78	0.14
Year * Preceding rice cultivar * Planting date	4	52672	0.35	0.84

**: Significant at the 5% level **: Significant at the 1% level*

3.3 Influence of Rice-sorghum Double Cropping

Sustained production of rice and sorghum on available vertisols would increase total cereal availability. Hence, double cropping of rice and sorghum is interesting for local farmers because the system maintains the production of the latter which is the traditional staple food [4]. This scheme can also provide rice for households' consumption or commercialization [1,7]. Rainfed sorghum is dominant but growing dry season or transplanted sorghum on vertic soils is an opportunity to strengthen food security. Some farmers succeed in generating a surplus. Income-based strategies increasingly involve the sale of part of the grain harvest. Dry season sorghum is overall the most appreciated cereal and is sold in larger proportions at a higher price, especially when it is supplied to towns [5].

Another interesting feature of the rice-sorghum double cropping system is that grain production is increased without need for additional land. This form of agricultural diversification or intensification, although in an embryonic state in the Far-Northern Region of Cameroon, deserves a particular attention because of yield fluctuations and risks of crop failure. In 2009 rice yields were relatively lower due to reduced rainfall. The following year with improved rainfall, there was a substantial paddy rice yield increase. The risk of failure also concerns dry season sorghum, the second crop in the system, and farmers are reluctant to miss its transplanting period [7]. Since the preference of local farmers is on dry season sorghum, the few who produce rice minimize the risk by using less than 30% of cultivated vertisols for rice production [4].

Dry season sorghum production is mainly determined by soil water content at transplanting. Because the dry season comprises most of its growing cycle, one may suggest the adoption of early transplanting or the use of cultivars adapted to late plantings. Under upland conditions and with plantings taking place before the 20th of November, no significant difference among the dry season sorghum sowing dates was observed. Under lowland conditions however, differences were observed among the sowing dates [1]. In 2010, higher yields were obtained with the two early sowings while best performances were recorded with late sowings in 2009 under lowland conditions. These differences could be attributed to fluctuations in soil moisture throughout sites and years [6], but soil water content was not monitored.

The time for transplanting dry season sorghum is determined empirically by growers after the last rains, when the soils are still moist to ensure seedling re growth, but are still dry enough to avoid seedling decay [7]. Abundant water from rains is not favorable to dry season sorghum establishment and at the same time, low soil moisture with late plantings is not desirable as seedlings and plants thrive to complete the growing cycle. Monitoring soil moisture to determine the best transplanting period was suggested but there is high uncertainty on the occurrence of the late rains [13]. One of the solutions adopted by local farmers is the use of successive plantings in nurseries [7,21]. Another option is the use of varieties adapted to late plantings such as ‘’Guelendeng’’ which may have contributed to mask the effects of planting date in this experiment. The recourse to relay plantings of dry season sorghum before rice harvest is also a potential explanatory factor to the non-significance of the planting date effect.

The success of dry season sorghum requires good Co-ordination of the nursery plant production period and the replanting date. Farmers perform staggered sowing in nurseries every five to 10 days from August onwards to obtain seedlings suitable for transplantation throughout September and October [21]. In general, rice produced more in the wetter year and dry season sorghum in the driest year. Although differences observed in yields are explained using the contrast in rains between 2009 and 2010 or the influence of preceding rice cultivar, other factors are also important for the phenology of dry season sorghum including the response to photoperiod or to low temperatures [9].

In extensive dry sorghum production systems, the crop is not fertilized. Nutrients are mainly provided by natural processes such as sedimentation, nitrogen fixation, and atmospheric deposition. Researches on agricultural practices have demonstrated that fertilization at planting or transplanting stage has no significant effect on dry season sorghum yield in

Northern Cameroon [21,22]. This was explained by low soil moisture during the dry season [22]. Dry season sorghum could better benefit of residual fertilizer applied to rice as first crop in the double cropping system. The annual application of 150kgha^{-1} of urea and 200kgha^{-1} NPK 22-10-15 (for a total of 113kgNha^{-1}) as presently recommended for rice production would not sustain both rice and dry sorghum needs in a long term. In this double crop cereal system (rice-sorghum), nitrogen fertilizer applications need to be substantial to prevent a rundown of soil fertility. Similar observations were made under lowland conditions [1]. Further work should determine adequate fertilizer levels for the rice-sorghum double cropping systems that ensure a positive nutrient balance for a sustained production.

This study demonstrates that double cropping of upland rice and dry season sorghum is a sound option to increase cereal production in the semi-arid region in Northern Cameroon. Growing rice as a precedent crop to traditional dry season sorghum ensures three to four times more output of cereals from the cultivation of the same plots than when dry season sorghum alone is produced. The local Short-cycle-dry-season sorghum variety is very suitable to the double cropping system investigated as it tolerates late plantings and thus buffers efficiently counter effects that may result from delayed planting of sorghum to allow rice mature prior to its harvest. Since preceding rice cultivar revealed a significant effect, it is worthy dedicating efforts in choosing rice cultivars that suit better to the double cropping system. Versatile rice varieties that can be grown under various regimes (upland, lowland or irrigated conditions) are of great interest owing to their ability to cope with the variability of climatic conditions in the semi-arid region in Northern Cameroon.

4. CONCLUSION

Investigation of the possibility of producing rice and sorghum following a double cropping system on uplands vertisols in the Far-Northern Region of Cameroon has shown that the three rice cultivars SEBOTA 281.2, B22 and PRIMAVERA are suited for upland rainfed production on vertisols. As first crops in the system, they produced 2.6 to 5.2tha^{-1} of paddy. In both years cultivar SEBOTA 281.2 performed better than the other cultivars. The choice of rice cultivar has a significant impact on both individual crop yield and the system yield. Subsequent dry season sorghum grain yields ranged between 832 and 1819kgha^{-1}. Hence, producing rice in the rainy season did not hinder subsequent dry season sorghum production. The adoption of double cropping of rice and dry sorghum production on upland vertisols can significantly increase the availability of cereals in the Far North Region of Cameroon where cereal shortages, famine and low income are common among farmers. However, the needs for adequate fertilization to sustain the cereal double cropping system and the availability of short cycle rice cultivars are the main challenges.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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