Agroclimatic potential for cultivation of two sorghum cultivars in mixtures with okra and maize in a forest-savanna transition zone of Nigeria

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Abstract: *Agroclimatic potential for cultivation of two sorghum cultivars grown in mixtures with okra and maize was investigated in a forest-savanna transition zone of Nigeria at the Experimental Research Farmland of the National Horticultural Research Institutes (NIHORT) - Ibadan during. During the main five phenological stages of sorghum (*Sorghum bicolor (L.)* Moench) the agrometeorological variables were daily recorded and averaged on ten days,likewise the crops growth and productive variables were fortnightly measured . Two sorghum cultivars (Janare and Farin Dawa), okra (*Hibiscus esculentus *L. – cultivar NHAe 47-4) and maize (*Zea mais *L. – cultivar Suwan-1) were intercropped in simple randomized complete block design (RCBD) fitted into split plot arrangements with three replicates in two field trials during 2009 and 2010 cropping seasons. In 2010 the crops showed a longer growing season and received more rainfall compared to 2009 season (692 mm vs 487.2 mm). Instead in 2009 warmer temperatures were recorded compared to 2010 during the establishment, early vegetative stage (33.2 °C vs 32 °C), and the reproductive one (28.5 °C vs 27 °C). The mean grain yields of sorghum cultivars were significantly ($p<0.05$) higher in 2009, especially in the okra combinations with cultivars Farin dawa and Janare (0.84* and *0.72 t ha^{-1} respectively), than in 2010 (0.80* and *0.67 t ha^{-1} respectively). These results may be due to the higher mean soil temperatures occurred in 2009 at 5 and 20 cm, respectively of 28 °C and 26 °C, compared to the 2010 season, when the mean soil temperatures were of 27°C and 25 °C at 5 and 20 cm respectively. Generally, Farin Dawa accumulated more heat than Janare in both 2009 and 2010 from planting to maturity regardless of the cropping system.*
Keywords: *sorghum, okra, maize, forest-savanna, transition zone.*

Riassunto: *Il lavoro mira ad analizzare le potenzialità agroclimatiche della zona di transizione foresta-savana per la coltivazione di due cultivar di sorgo in coltura pura ed in consociazione con okra e/o mais. L'analisi è stata condotta durante le stagioni 2009 e 2010 in un campo sperimentale sito presso la Stazione Sperimentale dei National Horticultural Research Institutes (NIHORT) di Ibadan (Nigeria).*
*Cinque periodi fenologici di sorgo (*Sorghum bicolor (L.)* Moench) hanno costituito l'unità di tempo per le indagini. Durante tali periodi, le principali variabili agrometeorologiche sono state misurate con passo giornaliero e trasformate successivamente in valori medi o totalizzati con passo decadale. A ciò si sono aggiunte misure biologiche sulla coltura e relative a diverse variabili di crescita e di produzione. Le due cultivar di sorgo (Janare e Farin Dawa), okra (*Hibiscus esculentus *L. – cultivar NHAe 47-4) e mais (*Zea mais *L. – cultivar Suwan-1) sono state inserite in un disegno sperimentale a blocchi randomizzati completi (RCBD) realizzato con tecnica split – splot e che prevedeva tre repliche. I risultati conseguiti hanno mostrato che la stagione di crescita 2010 è stata relativamente più piovosa (692 millimetri contro 487 millimetri), meno calda e prolungata rispetto al stagione 2009, la quale è risultata dal canto suo più ricca di risorse termiche durante la fase iniziale di sviluppo (33.2 °C contro 32 °C), e la fase riproduttiva (28,5 °C vs 27 °C). I rendimenti medi del sorgo sono risultati significativamente più elevati ($p<0,05$) nella stagione 2009 specie se in combinazione con le cultivar di okra Farin Dawa e Janare (0,84 e 0,72 t ha^{-1}) rispetto alla stagione 2010 (0,80 e 0,67 t ha^{-1} rispettivamente). È ipotizzabile che ciò sia stato determinato dalla più elevata temperatura media del terreno del 2009 rispetto al 2010 a 5 cm (28 vs 26 °C) e a 20 cm (27 vs 25 °C). In generale per il periodo semina-maturazione e per gli anni 2009 e 2010 la cultivar Farin Dawa ha accumulato più calore rispetto a Janare.*
Parole chiave: *sorgo, okra, mais, zona di transizione foresta-savana.*

INTRODUCTION

Although Nigeria is among the largest producers of sorghum, this crop is not as popular in Nigeria as either rice or maize (Agboola, 1979). Nevertheless the sorghum shows some advantages: (i) it is a multipurpose crop, useful to feed humans or livestock, (ii) it presents a relatively high protein content (15%) compared with rice (Oryza sativa) (13%) and maize (11%) and (iii) it is a drought tolerant crop.

Sorghum is well-known for its capacity to tolerate conditions of limited moisture and to grow during periods of extended drought that would impede production for most other grain crops. It is one of the most drought-tolerant grain crops and by this point of view it is both an excellent ideotype to

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address genetic improvement of other cereals and an interesting reference crop to evaluate mechanisms of drought tolerance of other species (Tuinstra *et al.*, 1997).
Sorghum is able to endure quite arid conditions through both drought resistance and drought escape mechanisms as a result of its extensive root system, waxy leaves and ability to temporarily stop growth when the drought becomes excessive. A drought escape mechanism is exhibited when sorghum becomes dormant under adverse water conditions but resumes growth when water relations improve even after relatively severe drought. Early drought stops growth before floral initiation and the plant remains vegetative but it will resume leaf and flower production when conditions become favorable again for growth. Late drought stops leaf development but not floral initiation.
For high yields, cultivars with cycle from 110 to 130 days require 450 – 650 mm of water (Doorenbos and Kassam, 1979). Furthermore, in order to maximize sorghum yields, soil moisture should be maintained above 55% of the available water capacity in the rooting zone of the soil profile throughout the growing season. When the growing period is long, stalking cultivars can recover by producing additional stalks with bearers, even if critical water deficits occur during vegetative growth. Extreme water deficits during the flowering period reduce pollination or cause spikes to dry out. Nevertheless the decrease of the resultant yield can be partially compensated by additional stalks with spikes (Doorenbos and Kassam, 1979).
Studies have equally shown that greatest reduction in okra yield occur when stress is imposed at the flowering stage. Similarly moisture stress during the pod filling stage resulted in more than 70% reduction in fruit yield of okra, while the lowest reduction in fruit yield was observed when moisture stress occurred during the vegetative stage (Mbagwa and Adesipe, 1987). Some later studies have suggested that flowering stage is the most sensitive to stressful conditions (Bänziger *et al.*, 1999). The selection of crop genotypes for tolerance to midseason drought stress has been found to improve the broad adaptation and the specific adaptation to drought environments. (Chapman *et al.*, 1997).
Research into rice and maize cultivation has been extensive in nearly all the eco-climatic zones of Nigeria, but in contrast the research endeavor in sorghum is not only small but restricted to the savanna region. Notable examples are those by Curtis (1968), Kassam and Andrews (1975), Leng (1982), Obilana (1983), Doggett (1988) and Craufurd and Aiming (2001).
Therefore it is not surprising that sorghum cultivation is restricted to the northern part of Nigeria where it is usually intercropped with maize, millet and cowpea (Agboola, 1979). However, Bello (1997) has investigated and highlighted the agro-climatic potential of the forest-savanna transition zone of Nigeria for the cultivation of sorghum. Based on his finding, it would appear that with changes in ecological boundaries resulting from changing in land use and climate pattern, the exploitation of the transitional humid zone may offer options for increase of sorghum production in the country. Currently the scientific literature is scarce of these studies for this zone . Moreover in forest-savanna transition zone of southwestern Nigeria, the traditional farmers are more satisfactory grow different species of crops than one. Indeed it is cheaper for farmers to grow many of their own requirements than to buy them (Kurt, 1984, Gomez and Gomez 1986). Therefore, the common cropping system in the zone is intercropping and the common crop combinations include maize-cassava, maize-mellon, maize-okra intercrop. At the same time there is a lack of information on maize-sorghum and sorghum-okra intercrop.
Therefore the basic aim of this research is to promote a wider adoption of Soghum to improve cropping systems and overall to enhance the results of the traditional intercrops.

MATERIALS AND METHODS

Experimental site

The experiment was carried out at Experimental, Teaching and Research Farmland of the National Horticultural Research Institutes (NIHORT), Ibadan (7° 22'N, 3° 50'E) during the 2009 and 2010 cropping seasons (Fig. 1). The study area is characterized by a tropical climate with distinct wet and dry seasons. The wet season is the effect of the moist southerly monsoon blowing from the Atlantic Ocean, whilst the dry season is the effect of the continental North Easterly harmattan winds blowing from the Sahara desert.
The resulting rainfall pattern is bimodal with the main rainy season in April-July period, while the secondary one is in August-October period. The annual rainfall ranges between 1400 and 1500 mm in Ibadan and its environs. Isolated and scanty rains usually start in mid-March and steadily increase to reach the peak values in July followed by a short break in August and another peak in September.

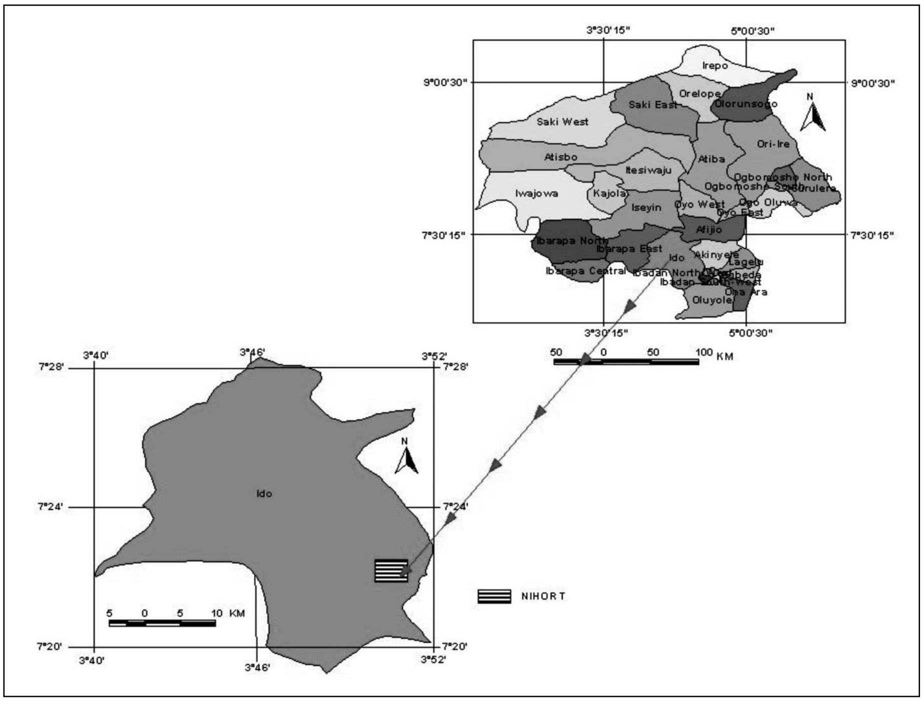


Fig. 1 - Location of NIHORT within Ido local government area in Oyo State, Nigeria.
Fig. 1 - Localizzazione del NIHORT all'interno dell'area governativa Ido dello Stato di Oyo.

The dry season is normally from October to March and it is often characterized by hot days.
The region is relatively hot with mean annual air temperature of about 30°C. The greatest variation in temperature is experienced between July (25.7°C) and February (30.2°C). Extreme values of relative humidity are respectively reached at the peak of dry season (February: 37-54%) and during the rainy season (from June to September: 78-85%) (Adejuwon 1971).

Crop management
Two cultivars of Sorghum (Farin Dawa and Janare), one of maize (Suwan 1) and one of okra (NHAe 47-4) have been used in two field trails during both seasons adopting the species e combinations described in Tab. 1. Two - four seeds of sorghum, maize and okra were planted at 2.5 cm depth. Sorghum was planted three weeks after okra and maize to allow the establishment of these two latter. Spacing was 90 x 60 cm for Sorghum (2 seedlings/stand), 90 x 30 cm for maize (1 seedling/stand) and 90 x 30 cm for okra (1seedling/stand).
Each plot size was 6 x 3 m for a total plot size of 100 x 20 m. In both seasons, land preparation was carried out by disc-ploughing and ridging. Plots were hoe weeded at third and sixth h weeks after planting along with other cultural practices. Fertilizer was applied into furrows at mid-interrow two weeks after the okra and maize emergence and was covered with soil.

Combination	Acronyms
white sorghum	S1
red sorghum	S2
maize/white sorghum	MS1
maize/red sorghum	MS2
okra/white sorghum	OS1
okra/red sorghum	OS2
maize/okra/white sorghum	MOS1
maize/okra/red sorghum	MOS2

Tab. 1 - Sorghum monocultures and different crops combinations of sorghum-maize-okra considered for the experimental plots and adopted acronyms.
Tab. 1 - Monocolture e consociazioni di sorgo, mais e okra oggetto di sperimentazione e relativi acronimi.

The experimental plots were arranged in a randomized complete block design (RCBD) fitted into split-plot design with three replicates. Three data-sets, concerning the growth and productive variables and the agro-climatic indices, were collected during the main critical phenological stages.
Meteorological data, representative of the fields microclimatic conditions, were daily recorded by a ground weather station located at 200 m near to the experimental site and then processed into decadal values. The following meteorological variables were daily monitored: rainfall (Rr, mm), mean relative humidity (Rh, %), open water evaporation (Ev, mm), maximum and minimum temperature (Tx and Tn, °C), sunshine hours, wind speed at a height of 2m (Ws, ms^{-1}).

Growth and productive variables

Per each plot the following growth variables were measured on a sample of plants: plant height (cm), leaf area (cm^2), number of leaves per plant, stem diameter (mm).Leaf Area LA (cm^2) was determined by a no-destructive method, carrying out measurements on 10 leaves per plot and then computing the respectively averages. Specifically, the okra LA was estimated following the equation 1 (Asif, 1977) and the LA of each single leaf blade was assessed for sorghum and maize following the equation 2 (Stewart and Dwyer, 1999).
(1) LA=115X- 1050
where L is the length of mid rib (cm).
(2) $LA= (L \times W) * L_{af}$
where L is the length (cm), W is the maximum width (cm) and L_{af} is the leaf area factor. For this latter, a value of 0.75 has been adopted, facing to reported values of 0.75 (Montgomery, 1911), 0.73 (Mckee, 1964), 0.72 (Keating and Wafula, 1992), 0.79 (Birch *et al.*, 1998) and 0.74 (Stewart and Dwyer, 1999).
Per each plot the following productive variables, concerning the indicated species, were measured: grain yield (sorghum and maize), panicle length (sorghum), cob weight (maize), weight of 100 grains (maize), pods number per plant and pods weight, length and diameter (okra).

Statistical analysis

Analysis of variance was carried out by set methods (Steel *et al*. 1997) using the PROC GLM procedure of the SAS Statistics package (SAS Institute Inc., 2000). The cropping pattern and cultivars were considered as random effects, while the planting seasons were considered as fixed effects. Cultivars and cropping patterns mean differences within each planting season were separated using Fisher's Least Significant Difference (LSD) test at P ≤ 0.05.

RESULTS AND DISCUSSION

The results were discusseded considering the data recorded for white and red sorghum grown alone as referencedata-set that therefore was matched with the data obtained for the other combinations of species (the intercropping with maize and/or okra).

Agrometeorological variables

The 10-days mean values measured for Tx, Tn, Rr Rh and Ws during both seasons and the main phenological stages of sorghum are shown in Figg. 2 and 3.

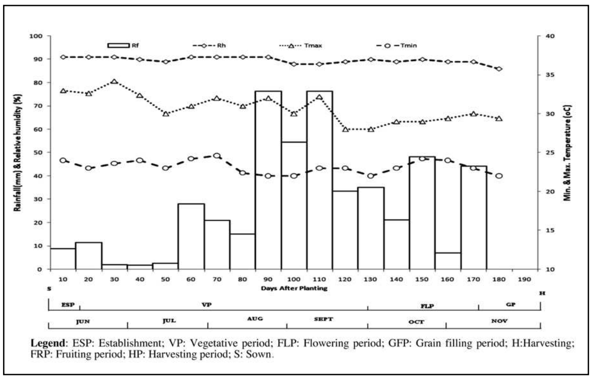


Fig. 2 - Time series of main agrometeorological variables during different phenological stages of experimental crops in 2009 season (June-November).
Fig. 2 - Serie storiche delle principali variabili agrometeorologiche durante le differenti fasi fenologiche per la stagione 2009 (Giugno-Novembre).

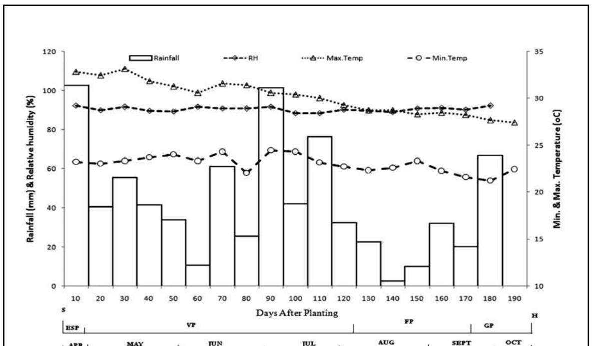


Fig. 3 - Time series of main agrometeorological variables during different phenological stages of experimental crops in 2010 season (June-November).
Fig. 3 - Serie storiche delle principali variabili agrometeorologiche durante le differenti fasi fenologiche per la stagione 2010 (Giugno-Novembre).

The total rainfall occurred in 2010 season was higher than 2009 (692 mm in 2010 vs. 487.2 in 2009) as result of the higher precipitation during the vegetative (537.5 mm vs 366.6 mm) and reproductive (154.5 mm vs 120.6 mm) phase.
As the figures 2 and 3 show, the temperature trends during both seasons follow the typical one of the Nigeria savanna area (Olaniran and Babatolu, 1987). Minimum temperature ranged between 22 and 24 °C in 2009 and between 21.2 and 23.4 °C in 2010. Maximum temperature ranged between 28 and 33 °C in 2009 and between 27 and 32 °C in 2010. During the planting, establishment and early vegetative stages warmer temperatures were recorded compared to the reproductive stages in both years2009 (24 vs 22 and 33 vs 28 °C) and 2010 (23 vs 22 and 31vs 27 °C).
During the 2009 season the mean minimum temperature was 24 °C during the establishment stage (ESP) but dropped to 23°C during the flowering period (FLP) while the least minimum temperature of 22°C was observed during the grain filling period (GFP). The 2010 growing season experienced a much lower minimum temperature with recorded values of 23.2, 22.57 and 21.6°C for ESP, FLP and GFP respectively. Maximum

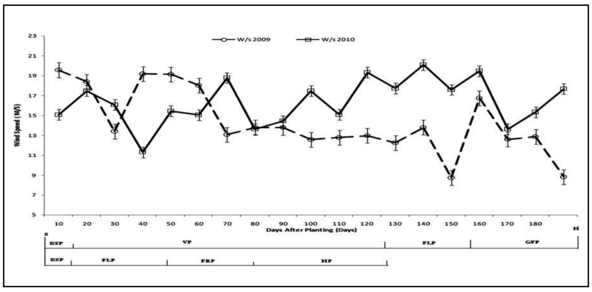


Fig. 4 - Wind speed (m s^{-1}) during 2009 and 2010 seasons.
Fig. 4 - Velocità del vento (m s^{-1}) nelle stagioni produttive 2009 e 2010.

temperature in 2009 season dropped from 33°C at ESP, to 29.3°C at FLP, while 30°C was recorded at GFP. In 2010, maximum temperature values were 32.7, 28.71 and 28.24°C at ESP, FLP and GFP, respectively.
Fig. 4 shows Ws (m s-1) in 2009 and 2010. Ws at 10 and 60 days after planting (DAP) was higher during 2009 (19.6 and 13.4 m s-1) compared to 2010 (11.3 and 15.1 m s-1). However, Ws at 70 and 180 DAP was higher during 2010 (13.6 and 20.1 m s-1) than 2009 (8.7 and 16.7 m s-1). In any case the maximum wind speed reached during windy days was not enough to cause physical damage for the crop

Treatments	2009			2010		
	GDDPI	GDDFL	GDDGM	GDDPI	GDDFL	GDDGM
White sorghum						
S1	1909	2212	2916	1779	2289	2975
OS1	1946	2259	2972	1779	2317	3030
MS1	2067	2381	3087	1835	2435	3149
MOS1	2116	2412	3099	2077	2499	3198
Red sorghum						
S2	1691	2200	2904	1757	2265	2881
OS2	1696	2260	2881	1785	2284	3030
MS2	1981	2380	3048	1841	2410	3077
MOS2	2025	2399	3086	2077	2481	3099
LSD(0.05)	110.3	76.07	35.07	74.43	36.73	62.52
White sorghum (mean)	2009	2316	3018	1868	2385	3088
Red sorghum (mean)	1848	2310	2980	1865	2360	3022
LSD (0.05)	81.61	55.04	45.82	72.84	34.89	21.57
Alone sorghum (mean)	1800	2206	2910	1768	2277	1569
Sorghum/okra (means)	1821	2260	2927	1782	2301	1598
Sorghum/ maize (means)	3058	3571	4612	2756	3639	3236
Sorghum/maize/ okra (mean)	3128	3612	4641	3116	3739	3286
LSD (0.05)	52.91	34.00	56.56	71.24	33.05	41.61

GDDPI: GDD from sowing to panicle initiation; GDDFL: GDD from sowing to flowering; GDDGM: GDD from sowing to maturity.

Tab. 2 - Growing degree days or heat units accumulation of two Sorghum cultivars as influenced by intercropping with Okra and Maize in 2009 and 2010.
Tab. 2 - Cumuli di unità di caldo (gradi giorno) per le due cultivar di sorgo in coltura pura o consociate con mais e/o Okra.

because the windy events occurred when the plants were fully established and approaching the ripening. On the other hand, during the days with lower wind speed, the proper conditions to receive sunlight for maximum photosynthesis were occurred for the plants.

Thermal resources expressed as growing degree days (GDD) from sowing to maturity are shown in Tab. 2. From planting to maturity more heat was cumulated by the white sorghum genotype (S1) than the red one (S2) in both seasons.

During **2009 the cumulative** GDD, from sowing to panicle initiation, reached the threshold of 1909 °C for S1, preceded respectively by OS1 (1946°C), MS1 mixtures (2067°C) and MOS1 (2116 °C). Likewise the values for red sorghum combination reached 1691°C for S2, preceded respectively by OS2 (1696 °C), MS2 (1981°C) and MOS2 (2025°C).

During **2010 the cumulative** GDD, from sowing to panicle initiation, for white sorghum was 1779°C for both S1 and OS1, preceded by MS1 (1835°C) and MOS1 (2077 °C). The values for red sorghum combination ranged from 1757°C for S2, followed by OS2 (1785 °C), MS2 (1841 °C) and MOS2 (2077 °C). For both years similar relations were observed for the periods from sowing to flowering and from sowing to maturity.

Values of soil temperature during crop season (not shown in figures) were higher in 2009 (28 and 26 ˚C at 5 and 20 cm respectively) than in 2010 (27 and 25 ˚C at 5 and 20 cm respectively).

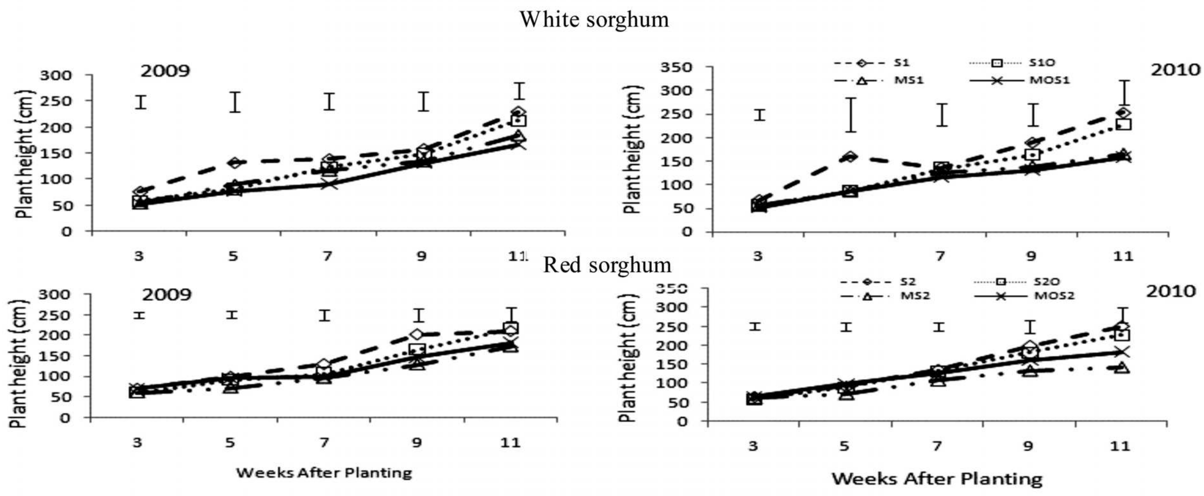
Growth characteristics

The main biometric characteristics of the two sorghum cultivars in monoculture and in mixtures (MS1, MS2, OS1, OS2, MOS1, MOS2) at 3, 5, 7, 9 and 11 weeks after planting (WAP) are briefly commented hereafter.

Plant height of sorghum (Fig. 5)

In **2009**, the plant height of white sorghum (S1) in both monoculture and mixtures was statistically different at 5, 7 and 11 WAP, while red sorghum (S2) showed no significant differences ($p<0.05$) in all sampling time, except at 5 WAP for the treatments with red sorghum (S2). More specifically S1 increased from 76.3 to 229.4 cm whereas S2 increased from 71.0 to 210.7 cm at 3 and 11 WAP respectively. OS1 increased from 59.0 cm 212.8 cm while OS2 increased from 59.9 to 215.8 cm at 3 and 11 WAP respectively. MS1 increased from 53.7 to 184.8 cm whereas MS2 increased from 60.6 to 174.2 cm at 3 and 11 WAP respectively. Finally MOS1 increased from 52.6 to 166.6 cm while MOS2 increased from 69.4 to 182.9 cm at 3 and 11 WAP respectively.

In **2010**, plant height of sorghum was significantly different at 5, 9 and 11 WAP for treatments with white sorghum (S1) and red sorghum (S2). More specifically S1 increased from 76.3 to 229.4 cm, whereas S2 increased from 71.0 to 210.7 cm. OS1 increased from 56.9 cm to 227.8 cm whereas OS2 increased from 58.4 to 227.7 cm. MS1 increase from



MS1: Maize/ White Sorghum Intercrop; MS2: Maize/Red Sorghum Intercrop; MOS1: Maize/Okra/White Sorghum Intercrop; MOS2: Maize/Okra/Red Sorghum Intercrop; S1: White Sorghum (Farin Dawa);S2: Red Sorghum (Janare); SO1: White

Fig. 5 - Effects of intercropping with maize and okra on the Plant height (cm) of two sorghum cultivars in 2009 and 2010 seasons.

Fig. 5 - Effetti della consociazione con mais e okra sull'altezza (cm) delle piante di sorgo delle due cultivar in esame per le stagioni produttive 2009 e 2010.

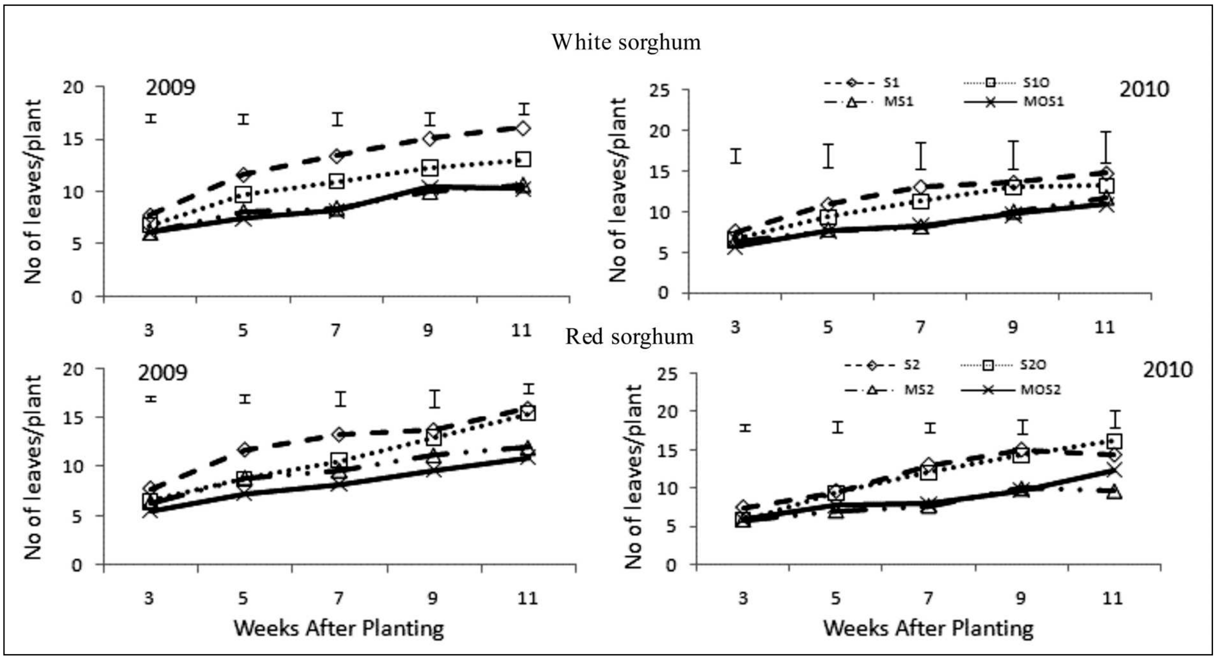


Fig. 6 - Effects of Intercropping with okra and maize on the number of leaves of the two sorghum cultivars in 2009 and 2010 seasons.
Fig. 6 - Effetti della consociazione con mais e okra sul numero di foglie delle piante di sorgo delle due cultivar in esame per le stagioni produttive 2009 e 2010.

55.7 to 165. 7 cm, whereas MS2 increased from 62.8 to 143.0 cm at 3 and 11 WAP respectively. Finally MOS1 increased from 51.7 to 158.2 cm from 3 and 11 WAP while MOS2 increased from 65.3 to 182.8 cm at 3 and 11 WAP respectively.

Number of leaves per plant of sorghum (Fig. 6)
In **2009 season**, the number of leaves per sorghum plant of S1 in both monoculture and mixtures was statistically different for all the sampled plots. Similarly S2 cultivar showed significant differences ($p<0.05$) in all plots with treatments containing S2. Number of leaves per plant in monoculture S1 ranged from 7.8 to 16.1 whereas in S2 increased from 7.8 to 16.0 at 3 and 11 WAP respectively. OS1 increased from 6.8 to 13.0 leaves while in OS2 it increased from 6.6 to 15.4 at 3 and 11 WAP respectively. MS1 increased from 6.1 to 10.7 whereas MS2 increased from 6.33 to 12.00 at 3 and 11 WAP respectively. Finally MOS1 increased from 6.1 to 10.3 while MOS2 increased from 5.56 to 10.99 at 3 and 11 WAP respectively.
In **2010 season**, sorghum showed a number of leaves per plant significantly different in treatments containing S1 at all sampling times. Similarly, the difference was significant in treatments containing S2 at all sampling times. Number of leaves per plant for S1 increased from 7.6 to 14.8 whereas values for S2 ranged from 7.5 to 15.0 at 3 and 9 WAP respectively. OS1 increased from 6.67 to 13.2 whereas OS2 increased from 5.8 to 16.1 at 3 and 11 WAP respectively. MS1 increased from 6.4 to 11.8 whereas MS2 increased from 5.8 to 10.0 at 3 to 9 WAP respectively. Finally MOS1 increased from 5.8 to 10.9 at 3 and 11 WAP whereas MOS2 increased from 5.9 to 12.3 at 3 and 11 WAP respectively.
In terms of number of leaves per plant, both sorghum cultivars perform better in sorghum/okra intercrop than in sorghum/maize intercrop.

Leaf area of sorghum (Fig. 7)
In **2009 season**, leaf area of S1 in both monoculture and mixtures was statistically different at all sampling times. Similarly S2 cultivar showed significant difference ($p<0.05$) at all sampling times except at 3WAP in mixtures containing S2. S1 increased from 293.1 to 850.7 cm^2 at 3 and 11 WAP respectively, whereas leaf area of S2 alone increased from 199.1 to 775.8 cm^2 at 3 and 9 WAP respectively. Leaf area of S1 in SO1 increased from 164.8 cm^2 at 3 WAP to 923.3 cm^2 at 11 WAP while leaf area of S2 in SO2 increased from 159.8 to 819.1 cm^2 at 3 and 9 WAP respectively. MS1 increased from 173.1 to 596.3 cm^2 whereas MS2 that increased from 136.2 to 587.1 cm^2 at 3 and 9 WAP respectively. Finally MOS1 increased from 132.1 to 558.7 cm^2 at 3 and 11 WAP whereas

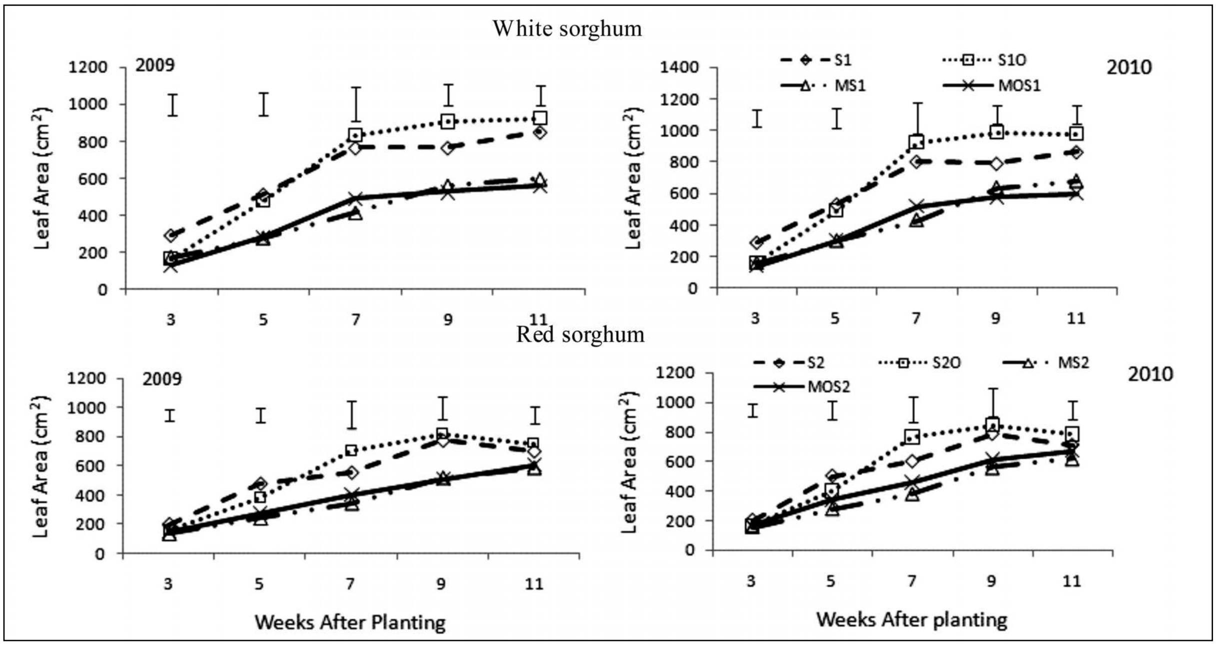


Fig. 7 - Effects of intercropping with okra and maize on the leaf area (cm^2) of the two sorghum cultivars in 2009 and 2010 seasons.
Fig. 7 – Effetti della consociazione con mais e okra sull'area fogliare (cm^2) delle piante di sorgo delle due cultivar in esame per le stagioni produttive 2009 e 2010.

MOS2 increased from 148.1 to 605.2 cm^2 at 3 and 9 WAP respectively.

In **2010 season**, leaf area of S1 was significantly different at all sampling times for treatments containing S1 cultivar. Similarly, the difference in leaf area of red sorghum was significantly different for treatments containing S2 at all sampled occasions except at 3 WAP. S1 increased from 289.5 to 865.8 cm^2 whereas S2 increased from 203.7 to 789.1 at 3 and 9 WAP respectively. SO1 increased from 162.5 cm^2 to 976.0 cm^2 whereas SO2 increased from 167.4 to 848.5 cm^2 at 3 and 9 WAP respectively. MS1 increased from 158.4 to 677.4 cm^2 whereas MS2 increased from 154.0 to 620.2 cm^2 at 3 and 11 WAP respectively. Finally MOS1 increased from 142.0 to 600.1 cm^2 whereas MOS2 increased from 166.3 to 668.8 cm^2 at 3 and 11 WAP respectively.

In terms of leaf area both sorghum cultivars perform better in sorghum/okra intercrop than in sorghum/maize intercrop.

Stem Diameter of sorghum (Fig. 8)

During the **2009 season**, stem diameter of S1 in both monoculture and mixtures was statistically different at all sampling times. Similarly the stem diameter of S2 cultivar showed significant difference ($p<0.05$) at all sampling times in treatment containing S2 while no significant different between sorghum cultivars.

Stem diameter of S1 ranged from 24.9 to 34.8 mm whereas S2 ranged from 25.2 to 35.4 mm between 5 and 11 WAP . SO1 increased from 23.5 to 30.3 mm while SO2 increased from 23.9 to 30.7 mm. MS1 increased from 19.1 to 24.2 mm whereas MS2 increased from 15.6 to 19.1 mm. Finally MOS1 increased from 14.0 to 19.7 mm while MOS2 increased from 13.5 to 17.3 mm.

During the **2010 season** the difference in stem diameter of white sorghum was significant for both treatments S1 and S2 at all sampled occasions. S1 increased from 28.3 to 34.5 mm whereas the values in S2 alone increased from 28.4 to 36.5 mm between 3 and 11 WAP. Stem diameter of S1 in SO1 increased from 24.38 to 32.94 mm whereas SO2 increased from 24.6 to 34.4 mm. MS1 increased from 14.3 to 20.0 mm whereas MS2 increased from 13.0 to 18.9 mm between 3 and 11 WAP. Finally MOS1 increased from 14.05 to 17.37 mm whereas MOS2 increased from 13.28 to 20.28 mm.

Similarly to the results for the leaf area Bboth sorghum cultivars perform better in sorghum/okra intercrop than sorghum/maize intercrop in terms of stem diameter. . These results can be explained as consequences of the prevalent antagonistic character of the symbiosis sorghum-maize.

Days to panicle initiation (heading), flowering and grain maturity of sorghum (Tab. 3)

Intercropping with okra affected only days from planting to flowering during 2009 and both days to

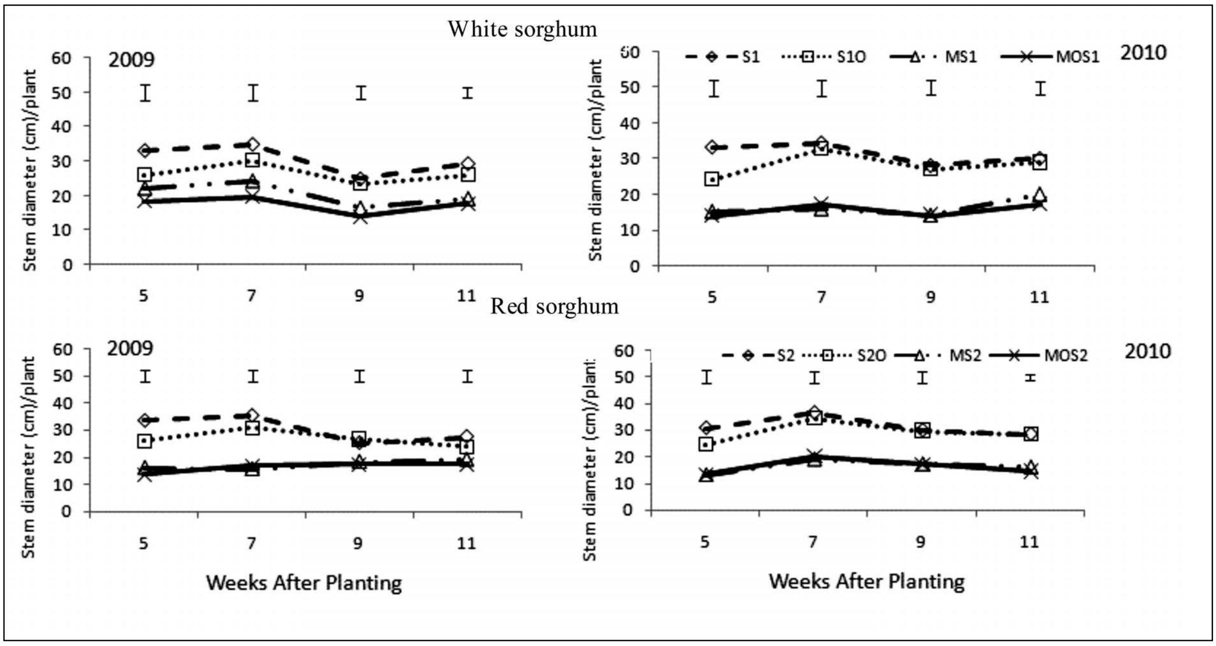


Fig. 8 - Effects of intercropping with okra and maize on Stem Diameter (cm) of the two sorghum cultivars in 2009 and 2010 seasons.
Fig. 8 - Effetti della consociazione con mais e okra sull'area fogliare (cm²) delle piante di sorgo delle due cultivar in esame per le stagioni produttive 2009 e 2010.

Treatments	2009			2010		
	Days from planting to Panicle Initiation	Days from planting to Flowering	Days from planting to Grain Maturity	Days from planting to Panicle Initiation	Days from planting to Flowering	Days from planting to Grain Maturity
White sorghum						
S1	96	127	166	110	125	164
OS1	96	129	169	112	127	167
MS1	99	136	176	119	133	174
MOS1	113	138	177	121	137	176
Red sorghum						
S2	95	126	165	98	124	164
OS2	96	129	164	99	125	167
MS2	100	136	173	114	132	175
MOS2	113	137	176	116	136	178
LSD(0.05)	4.20	4.20	2.09	5.99	2.06	1.53
White sorghum (mean)	101	132	172	116	131	170
Red Sorghum (mean)	101	132	169	107	129	171
LSD (0.05)	4.11	3.04	2.97	4.43	2.01	1.74
Sorghum alone (mean)	95	126	165	104	124	164
Sorghum/okra (mean)	96	129	166	105	126	167
Sorghum/maize(mean)	100	204	262	176	199	261
Sorghum/maize/okra (mean)	113	206	265	179	205	265
LSD (0.05)	4.01	1.87	3.84	2.86	1.95	1.95

Tab. 3 - Effects of intercropping okra and maize on the phenology of two sorghum cultivars in 2009 and 2010 seasons.
Tab. 3 - Effetto della consociazione con mais e okra sulla fenologia delle due cultivar di sorgo nelle anate 2009 e 2010.

flowering and to grain maturity during 2010. On the other hand the intercropping with maize affected significantly all the three selected phenological ranges both for 2009 and 2010.
Furthermore heading, flowering and grain maturity have been always attained earlier by mixtures sorghum-okra than mixtures sorghum-maize.
During **2009 season**, days to heading for white sorghum combinations have been 96 for S1 and OS1, followed by 99 for MS1 and 113 for MOS1 where for mixtures with red sorghum these days were respectively 95, 96, 100 and 113.
The days to flowering for white sorghum combinations have been 127 for S1, 129 for OS1, 136 for MS1 and 138 for MOS1 where for mixtures with red sorghum these days were respectively 126, 129, 136 and 137.
Days to grain maturity in treatments containing white sorghum (S1) have been 166 days for S1, 169 for OS1, 176 for MS1 and 177 for MOS1 whereas in mixtures with red sorghum these days were respectively 165, 164, 173 and 176.
For **2010 season** days to heading for white sorghum combinations ranged from 110 days of S1 to 112 days of SO1 to 119 of MS1 to 121 days of MOS1. Days to flowering in red sorghum combinations ranged from 98 days of S2 to 99 days of OS2 to 114 days of MS2 to 116 days of MOS2.
Days to flowering for mixtures with white sorghum ranged from 125 days of S1 followed by 127 of OS1, 133 of MS1 and 137 of MOS1 where for mixtures with red sorghum these days were respectively 124, 125, 132 and 136.
Days to grain maturity for mixtures with white sorghum ranged from 166 days of S1 to 169 days of OS1 to 176 days of MS1 to 177 days of MOS1 where for mixtures with red sorghum these days were respectively 164, 167, 174 and 176.

Treatments	2009			2010		
	Panicle Length (cm)	Grain weight/ head (g)	Grain Yield (t/ha)	Panicle Length (cm)	Grain weight/ head (g)	Grain Yield (t/ha)
White sorghum						
S1	46.0	69.5	1.05	71.0	65.8	0.88
OS1	48.7	60.5	0.84	57.8	58.8	0.80
MS1	50.0	51.0	0.65	60.3	43.8	0.61
MOS1	51.0	40.2	0.45	57.2	37.2	0.42
Red sorghum						
S2	49.7	66.1	0.94	70.7	41.2	0.91
OS2	50.0	55.8	0.72	56.4	51.5	0.67
MS2	51.5	39.8	0.64	52.5	37.6	0.53
MOS2	52.3	37.2	0.53	55.3	23.7	0.48
LSD (0.05)	1.08	9.04	0.07	13.05	28.69	0.25
White sorghum (mean)	48.9	55.3	0.75	61.6	51.4	0.68
Red sorghum (mean)	50.9	49.7	0.71	58.8	38.5	0.65
LSD (0.05)	1.15	9.73	0.13	13.14	17.74	0.17
Sorghum alone (mean)	47.8	67.8	1.0	70.9	53.5	0.90
Sorghum/okra (means)	49.3	58.2	0.78	57.1	55.2	0.74
Sorghum/maize (means)	50.8	45.4	0.65	56.4	40.7	0.57
Sorghum/ maize /okra (mean)	51.7	38.7	0.49	56.5	30.4	0.45
LSD (0.05)	1.21	10.42	0.19	13.25	6.79	0.09

Tab. 4 - Panicle Length, Grain weight/head (g) and Grain yield (t/ ha) of two sorghum cultivars as influenced by intercropping with Maize and Okra in 2009 and 2010 seasons.
Tab. 4 - Lunghezza del pannicolo, resa in granella per infiorescenza (g) e produzione totale (t / ha) delle due cultivar di sorgo in coltura pura o consociata con mais e/o okra per le stagioni 2009 e 2010.

Treatment	2009		2010	
	No of pods/plant	Pod yield (t/ha)	No of pods/plant	Pod yield (t/ha)
White Sorghum				
O	9	2.8	10	5.5
MO	6	2.0	12	4.3
OS1	10	3.1	22	9.9
MOS1	7	1.9	11	4.4
Red Sorghum				
O	12	4.2	23	9.5
MO	5	1.8	5	2.1
OS2	9	3.4	16	7.1
MOS2	6	2.1	10	3.6
LSD (0.05)	5.63	0.82	9.26	4.67
White sorghum (mean)	9	2.5	14	6.0
Red sorghum (mean)	8	2.9	14	5.6
LSD (0.05)	2.05	0.75	3.80	0.51
Okra alone (mean)	11	3.5	17	7.5
Okra/sorghum (mean)	10	3.3	19	8.5
Okra/maize (mean)	5	1.9	8	3.2
Okra/maize/sorghum (mean)	6	2.0	10	4.0
LSD (0.05)	3.24	1.32	10.35	3.6

Tab. 5 - Effects of intercropping sorghum cultivars and maize on the yield characters of okra in 2009 and 2010 seasons.
Tab. 5 - Effetti della consociazione con sorgo e/o mais e/o sulle caratteristiche produttive dell'okra nelle due annate 2009 e 2010.

Yield data evaluation
Yield is function of the integrated effect of all the yield components which are usually affected by the growing meteorological and environmental conditions, farmer activities and cropping pattern. Yields of single crops are hereafter discussed.

Sorghum yield
Tab. 4 shows panicle length, grain weight per head and grain yield of the two sorghum cultivars.
Statistical analysis shows that for 2009 (i) grain weight per head of sorghum alone and sorghum/okra are significantly higher than sorghum/maize and sorghum/maize/okra and (i) final yield of sorghum alone is significantly higher than sorghum/okra which in turn is significantly higher than sorghum/maize and sorghum/maize/okra. A similar behavior is present in 2010 with the only difference given by the non significance of the difference in the grain weight per head of sorghum alone and sorghum/okra.
During **2009 season**, panicle length for white sorghum mixtures ranged from 46.0 cm of S1 to 48.7 cm of OS1 to 50.0 of MS1 to 51 of MOS1 whereas for mixtures with red sorghum the values were respectively 49.7, 50, 51.5 and 52.3.
Grain weight per head of white sorghum ranged from 69.5 g of S1 to 60.5g of OS1 to 51 g of MS1 to 40.2 g of MOS1 whereas for mixtures with red sorghum the values were respectively 66.1, 55.8, 39.8 and 37.2.
Grain yield of white sorghum ranged from 1.05 tha^{-1} of S1 to 0.84 tha^{-1} of OS1 to 0.65 tha^{-1} of MS1 to 0.45 tha^{-1} of MOS1 whereas for mixtures with red sorghum the values were respectively 0.94, 0.72, 0.64 and 0.53.
During **2010 season** (Tab. 3) panicle length for white sorghum mixtures ranged from 71.0 cm of S1 to 60.3 cm of MS1 to 57.8 cm of OS1 to 57.2 cm of MOS1 whereas for mixtures with red sorghum the values were respectively 70.7, 56.4, 55.3 and 52.5 cm.
Grain weight per head for white sorghum mixtures ranged from 65.8 g for S1 to 58.8 of OS1 to 43.8 of

MS1 to 37.2 of MOS1 whereas for mixtures with red sorghum the values were respectively 51.5, 41.2, 37.6 and 23.7 g.
Grain yield per plot for white sorghum mixtures ranged from 0.88 t ha^{-1} of S1 to 0.80 of OS1 to 0.61 of MS1 to 0.42 of MOS1 whereas for mixtures with red sorghum the values were respectively 0.91, 0.67, 0.53 and 0.48 t ha^{-1}.

Okra yield

In **2009 season** (Tab. 5) white sorghum mixtures show the highest pod yield in OS1 (3.1 tha^{-1}) followed by O alone (2.8 tha^{-1}), MO (2.0 tha^{-1}) and MOS1 (1.9 tha^{-1}). On the other hand red sorghum mixtures show the highest pod yield for O (4.2 tha^{-1}), followed by OS2 (3.4 tha^{-1}), MOS2 (2.1 tha^{-1}) and MO (1.8 tha^{-1}). Furthermore the mean yields were statistically different.
Similarly during **2010 season**, white sorghum mixtures show the highest pod yield in in OS1 (9.9 tha^{-1}), followed by O (5.5 tha^{-1}), MOS1 (4.4 tha^{-1}) and MO (4.3 tha^{-1}) whereas in red sorghum combinations, the yield were decreasing from O (9.5 tha^{-1}) to OS2 (7.1 tha^{-1}), MOS2 (3.6 tha^{-1}) and MO (2.1tha^{-1}).

Maize yield (t ha^{-1})

Tab. 6 shows the maize yield and weight of 100 maize grains.

For **2009 season**, yields of different maize mixtures were not statistically different for treatments containing white sorghum (S1) while the difference was statistically significant for treatments containing red sorghum (S2).
Furthermore in treatments containing white sorghum, highest yield (1.86 t ha^{-1}) is obtained from maize alone (M), followed by 1.65 of MO 1.23 of MS1 and 1.14 of MOS1 whereas in red sorghum combinations, the yield were decreasing from M (1.41 t ha^{-1}), MO (1.24), MOS2 (0.97) and MS2 (0.82).
Weight of 100 grains of maize in the treatment containing white sorghum was highest in maize alone (18.40g), followed by maize/okra mixture (15.83) and MOS1 mixture (16.33). In red sorghum treatments, M also shows the highest weight (19.17 g) followed by MO (16.17), MS2 (15.1) and MOS2 (13.50).
For **2010 season** the highest yield has been obtained from M (1.95 t ha^{-1}) followed by MO (1.51), MS1 (1.36) and MOS1 (1.18). In red sorghum treatments, M also shows the highest yield (1.51 t ha^{-1}) followed by MO (1.4), MOS2 (0.96) and MS2 (0.93).
Weight of 100 grains of maize in the treatment containing white sorghum was highest in maize alone (18.27g), followed by MO (15.8), MOS1 (14.57) and MS1 (13.30). In red sorghum treatment

	2009		2010	
Treatments	Maize grain yield (tha^{-1})	Weight of 100 grains (g)	Maize grain yield (tha^{-1})	Weight of 100 grains (g)
White sorghum				
M	1.86	18.40	1.95	18.27
MO	1.65	15.83	1.51	15.77
MS1	1.23	14.83	1.36	13.30
MOS1	1.14	16.33	1.18	14.57
Red sorghum				
M	1.41	19.17	1.51	20.57
MO	1.24	16.17	1.42	17.80
MS2	0.82	15.10	0.93	15.67
MOS2	0.97	13.50	0.96	13.70
LSD (0.05)	0.86	3.23	0.92	3.79
White sorghum (mean)	1.47	16.35	1.50	15.48
Red sorghum (mean)	1.11	15.99	1.21	16.94
LSD (0.05)	0.42	2.27	0.42	4.66
Maize alone (mean)	1.64	18.79	1.73	19.42
Maize/okra (mean)	1.45	16	1.47	16.79
Maize/sorghum (mean)	1.03	14.97	1.15	14.49
Maize/okra/sorghum (mean)	1.06	14.92	1.07	14.14
LSD (0.05)	0.76	3.22	0.37	4.25

Tab. 6 - Effects on maize production of intercropping with sorghum and/or okra in 2009 and 2010 seasons.
Tab. 6 - Effetti della consociazione con sorgo e/o okra sulle caratteristiche produttive del mais nelle due annate 2009 e 2010.

M had also the highest weight (20.57 g), followed by MO (17.8), MS2 (15.7) and MOS2 (13.7).

The better performance of maize in 2010 can be attributed to a relatively steady and higher amount of rainfall across all the phenological stages compared with 2009 season which had a lower amount of rainfall. The same observation was made by Makinde *et al.*, (2009) working on maize-cucumber intercrop. These observations confirm the high sensitivity of maize to water shortage especially during the range of 40-60 days centered on the male flowering.

CONCLUSION AND RECOMMENDATIONS

This study confirms the agro climatic potential of the forest-savanna transition zone of Nigeria for intercropping between sorghum cultivars, Janare and Farin Dawa and okra (NHAe 47-4) and maize (Suwan-1). Results show that the relevant differences in mean daily air and soil temperatures and in rainfall during the two seasons, 2009 and 2010, significantly affected the crops growth and yield.

In both growing season the weather conditions were cooler during the vegetative and reproductive growth stages, than during the establishment and early vegetative periods. 2010 was more rainy and colder season compared to 2009. The results shows that the study area has a higher agroclimatic potential for the cultivation of okra with sorghum cultivars, Janare and Farin Dawa, than with maize (Suwan-1).

The combination of the two sorghum cultivars (Janare and Farin Dawa) with okra (NHAe 47-4) did not affect significantly the okra phenological development (i.e. vegetative growth, flowering and fruiting stages) and the sorghum growth and production in both seasons. The mean pod yields of okra in 2009 and 2010 seasons were significantly ($p \leq 0.05$) higher in sorghum intercrop than in maize intercrop. This may be probably due to the wide differences in the stages of growth and development in relation to resources requirement and utilization of sorghum and okra. Okra had largely reached physiological maturity before the phase of maximum growth of sorghum.

The mean grain yields of sorghum cultivars were significantly ($p<0.05$) higher in the 2009 season especially in okra combination with cultivars Farin dawa and Janare (0.84 *and* 0.72 t ha^{-1} respectively) than in the 2010 season. Perhaps this was due to higher mean soil temperature of 28°C and 26°C at 5 and 20 cm in 2009 season compared with 2010 season when mean soil temperature was 27°C and 25°C at 5 and 20 cm respectively. Generally, Farin Dawa accumulated more heat than Janare in both 2009 and 2010 seasons from planting to maturity regardless of cropping system.

Finally, in order to reduce the risk of crop failure for the farmers due to unpredictable weather conditions, okra/sorghum combination is highly recommended since it is able to maximize the crops performance in both meteorological conditions characterizing the two years of experiment and therefore it is able to reduce the impact of climate variability on the crops growth and production.

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