African Journal of Agricultural Research Vol. 6(14), pp. 3240-3246, 18 July, 2011
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR10.270
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

Effect of sowing date on *Striga* infestation and yield of sorghum (*Sorghum bicolor* [L.] Moench) cultivars in the Sudan savanna of northeast Nigeria

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Accepted 16 May, 2011

***Striga hermonthica* is a serious biotic constraint to sorghum production in the dry savannas of sub-Saharan Africa but the use of improved cultivars and appropriate planting dates may help to control the weed. A two year trial was conducted to evaluate the effect of sowing dates on four sorghum cultivars (improved: ICSV111, ICSV400, KSV8, and landrace: HANUNGIWA) under natural infestation with *S. hermonthica* in northeast Nigeria. In early sowing, the number of emerged *Striga* plants was twice the number found when sowing was delayed by 21 or 28 days. ICSV111 and ICSV400 had 25 to 110% fewer *Striga* shoots than KSV8 and HANUNGIWA. Although *Striga* infestation was significantly more on KSV8 this cultivar had a higher yield than the others except for ICSV111 which had the highest grain yield. KSV8 and HANUNGIWA produced significantly more grain when sown in the first week of July. The yields of ICSV111 and ICS400 increased substantially when sown in the fourth week of July. Farmers in the zone would maximize sorghum yield if improved cultivars are planted at the appropriate dates in *Striga* infested fields.**

Key words: Dry weight, landrace, sorghum grain, sowing date, *Striga hermonthica*.

INTRODUCTION

Striga hermonthica [Del.] Benth. is a serious biotic constraint to cereal production in the dry savannas of sub-Saharan Africa where over 100 million people lose half their crop production to this hemi-parasitic weed (Berner et al., 1995; Kanampiu et al., 2002). In West Africa, *Striga* infests over 64% (17 million ha) of the land planted to cereals, resulting in significant yield losses that range from 10 to 100% depending on crop and cultivar (Lagoke et al., 1991; Obilana and Ramaiah, 1992; Gressel et al., 2004). In Nigeria, sorghum (*Sorghum bicolor* [L.] Moench) which accounts for 34% of total cereal production (Akintayo and Sedgo, 2001) is one of the major cereals severely affected. *Striga* infestation in sorghum is reported to be higher in Nigeria than in other West African countries with about 80% (8.7 million ha) of land cropped to sorghum infested by this weed (Gressel et al., 2004). In a recent survey conducted in northeast Nigeria, Dugje et al. (2006) reported that out of 266 farmers' sorghum fields sampled, 94% were infested with *S. hermonthica*.

The control of *Striga* in cereals has been a major challenge to peasant farmers. Although several control measures have been recommended, yield levels of cereal crops continue to decline as a result of *Strig*a damage. However, Gressel et al. (2004) noted that if practised long enough, a combination of nitrogen fertilizer, intercropping and crop rotations, the use of tolerant cultivars and clean seed significantly reduces *Striga* damage. In northern Nigeria, out of 15 existing *Striga* control techniques identified by the farmers, hoe weeding and hand pulling, the application of inorganic fertilizer and manure, crop rotations, fallowing, and early planting are widely used (Emechebe et al., 2004).

In the Guinea and Sudan savannas of Nigeria sorghum is the major host for *Striga* reproduction (Weber et al., 1995). Dugje et al. (2006) reported that *Striga* emergence counts were generally lower in maize fields than in sorghum fields in the savanna zones of northeast Nigeria.

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Similarly, Weber et al. (1995) reported significant differences in the contribution of sorghum and maize in mixed cropping systems to the overall reproduction of *Striga*. According to Dugje et al. (2007) *Striga* control in sorghum is more challenging than in other cereal crops because sorghum matures late compared to maize and produces after-harvest sprouts which support the *Striga* plant to produce seeds.

A combination of sound cultural practices and resistant/tolerant crop cultivars has been proposed as a means of reducing losses from *Striga* infestation on crops (Wilson et al., 2000; Bayu et al., 2001; Rodenburg et al., 2006). Sowing date as an essential component of crop management could be manipulated to better control *S. hermonthica* in sorghum. As noted by Vissoh et al. (2008) managing sowing dates tries to exploit the opportunities while avoiding the risk associated with sowing at the time of optimal rainfall. Early sowing has drought risks but the advantage that the cereal has grown sufficiently before the parasite seeds are preconditioned and germinated. Late sowing may have drought spells that reduce grain yields but the advantage that *Striga* seeds may have gone into secondary dormancy in the absence of a suitable host. In Bénin, Gbèhounou et al. (2004) reported a linear relationship between sowing date and *Striga* infestation in sorghum. Vissoh et al. (2008) in southern Bénin observed four times more *Striga* in direct early sowing than in direct late sowing. Dugje et al. (2008) reported that sowing maize in mid-July reduced *Striga* infestation compared to sowing in mid-May or mid-June in parts of the northern and southern Guinea savanna of Nigeria, but grain yield in these zones was lower when maize was sown in mid-July than when sown mid-May or mid-June. Some studies have also reported significant interactions between cultivars and sowing dates on maize grain yield (Bunting, 1978; Graybill et al., 1991; Norwood, 2001; Darby and Lauer, 2002). Current information on the sowing date of improved sorghum cultivars in relation to yield and *Striga* infestation is very limited in the dry savannas of West Africa. A better understanding is needed of the effects of sowing date, integrated with improved cultivars, on yield and *Strig*a infestation. The objective of this study was to evaluate the effect of sowing dates and cultivars on *Striga* infestation and the grain yield of sorghum in a dry savanna ecology.

MATERIALS AND METHODS

Study site

The study was conducted in 2005 and 2006 at the IITA Crop Research site in Nzuda (11°15' N, 12°76' E) in the Sudan savanna of Borno State, Nigeria, under rain-fed conditions. The soil in Nzuda is sandy loam with organic carbon 5.4 g kg^{-1}, P 2.4 mg kg^{-1}, K 0.21 mg kg^{-1}, total N 0.84 g kg^{-1} and pH of 6.24. The soil sample was analysed for texture and chemical composition as described by Mehlich (1984) and Van Reeuwijk (1992). Total annual rainfall was 716 mm in 2005 and 894 mm in 2006. Weekly rainfall distribution during the study period in both years is presented in Figure 1. Average minimum temperature was 21.9°C in 2005 and 22.0°C in 2006. Average maximum temperature was 36.7°C in 2005 and 37.8°C in 2006.

Experimental design

The treatment design was a split plot with three replications. Sowing date was assigned to main plot and sorghum cultivars to subplot. Four sowing dates (July 7, July 14, July 21, and July 28) and three improved sorghum cultivars (ICSV 111, ICSV 400 and KSV 8) obtained from ICRISAT and a local landrace check (HANUNGIWA) were evaluated under natural infestation with *S. hermonthica*. A sowing date after July 14 was considered late. Farmers in this ecology generally plant sorghum the moment the rain starts in June but are often faced with crop failure from early season drought. Prior to planting, land was ploughed and ridged using draught animals. Planting distance was 0.75 m between rows and 0.40 m between plants. Four seeds were sown/hill and the seedlings were thinned to two plants/hill at 2 two weeks after planting (WAP). Each subplot was arranged in four rows of 5 m length. At planting, 40 kg ha^{-1} each of P as single super phosphate and K as muriate of potash was applied to all plots. Nitrogen fertilizer, in the form of urea was applied in two splits at the rate of 40 kg N ha^{-1} each at 1 and 5 WAP and 40 kg N ha^{-1} 5 WAP. All fertilizer was band-applied on ridges. Immediately after planting, gramozone (1:1-dimethly-4, 4'-bipyridinium dichloride) was applied at the rate of 3 L ha^{-1} to control weeds. Manual weeding was done at 2 and 7 WAP to control late emerging weeds. The number of emerged *Striga* plants in each plot was counted at 10 WAP. At maturity sorghum panicles and shoots were harvested and dried. Panicles were threshed and grain yield determined.

Statistical analysis

All data were subjected to an ANOVA using the PROC mixed procedure (Littell et al., 1996) of SAS (SAS Institute, 2001) with replicate treated as a random effect and sowing date and cultivars treated as fixed effects. *Striga* numbers were analysed after square root $(i + q)^{1/2}$ transformation where i is the number of emerged *Striga* m^{-2} and q = 0.5. Standard error of the difference (S.E.D) was estimated for each treatment. Differences between two treatment means were compared with t-test based on the S.E.D at 5% level of probability. Pearson's correlation coefficient between grain yield, shoot dry weight and *Striga* count was also computed using PROC CORR of SAS (SAS Institute, 2001).

RESULTS AND DISCUSSION

Sorghum grain yield

There was a significant year and cultivar effect on sorghum grain yield (Table 1). Two 2-way interaction between sowing date and cultivar was significant because the cultivars responded differently to the various sowing dates (Tables 1 and 2). Grain yields of ICSV 111 increased significantly as sowing date was delayed (Table 2). Except for the first sowing date (July 7) grain yield of ICSV 400 also increased significantly as the sowing date was delayed. The highest grain yields were obtained from ICSV 111 and ICSV 400 when sown on July 28. When sown on July 28, ICSV 111 had 2.69 times

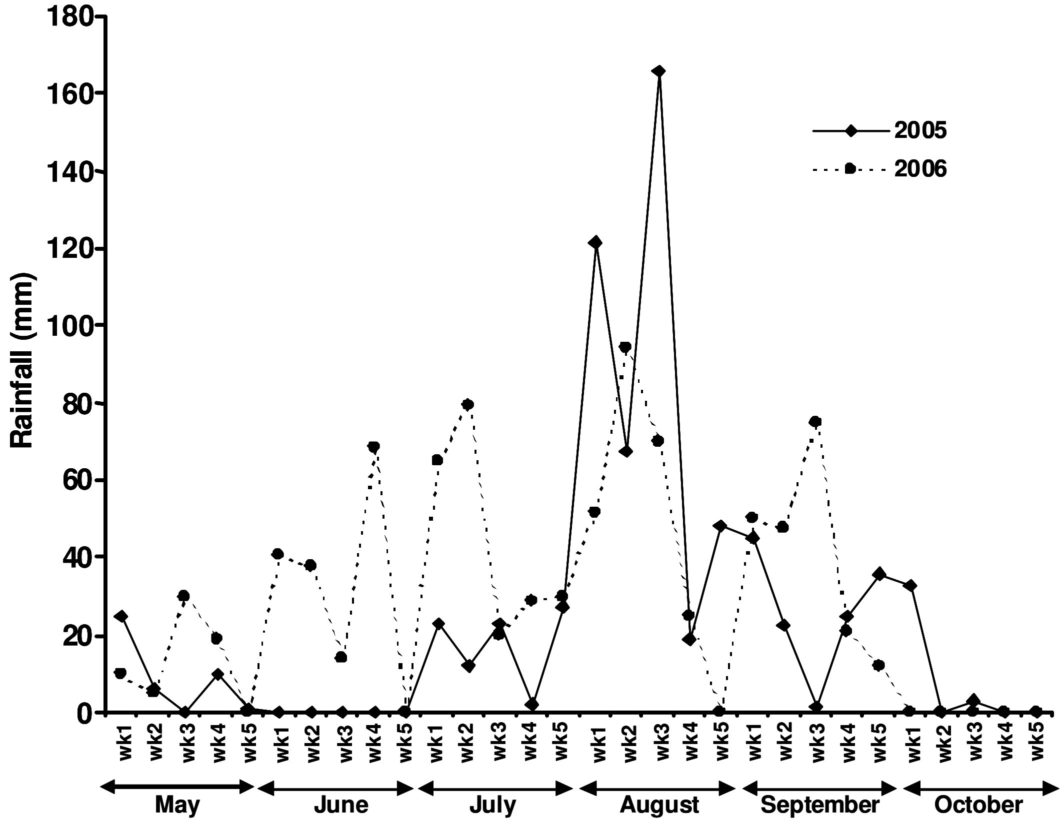

Figure 1. Weekly rainfall in 2005 and 2006 in Nzuda, Borno State, Nigeria.

Table 1. Probability of F-values of response of emerged *Striga* plant, fodder and grain yield of sorghum in 2005 and 2006 at Nzuda, Borno State, Nigeria.

		Grain yield (kg ha^{-1})		Shoot dry weight (t ha^{-1})		*Striga* count at 10 WAP[†]	
Effects	**Df**	**F-value**	**P-value**	**F-value**	**P-value**	**F-value**	**P-value**
Year (Y)	1	13.12	0.0053	6.50	0.0232	22.99	0.0003 [‡]
Sowing date (S)	3	0.40	0.7583	11.23	0.0005	3.14	0.0591
Y × S	3	1.13	0.3704	10.10	0.0009	1.15	0.3634
Cultivar (V)	3	4.75	0.0180	10.82	0.0007	7.99	0.0002
Y × V	3	1.56	0.2450	17.64	<0.0001	0.12	0.9502
S × V[Ψ]	9	3.08	0.0085	2.89	0.0116	0.46	0.8960
Y × S × V	9	1.30	0.2739	2.11	0.0558	0.52	0.8505

[†]WAP = Weeks after planting; [‡]values are square root-transformed ($(X + 0.5)^{1/2}$) before ANOVA; [Ψ]S × V = sowing date × cultivar interaction.

Table 2. Effect of sowing date and sorghum cultivar on grain yield (t ha^{-1}) in Nzuda, Borno State, Nigeria.

Variety	July 7	July 14	July 21	July 28
HANUGIWA (Local)	921.3	815.5	769.4	753.7
ICSVIII	663.4	1300.1	1487.4	1783.7
ICSV400	994.0	952.7	1088.3	1307.0
KSV8	1833.4	1047.5	1216.9	1064.0
SED		285.68		

Values represent two year mean. (S.E.D = Standard error of the difference between two treatment means).

more grain than when sown on 7 July and 1.37 times more grain than when sown on 14 July, ICSV 400 had 1.31 times more grain when sown on similar dates (Table 2). These two cultivars are early maturing and heading took place in the heavy rain of August (Figure 1) which predisposed the crop to diseases, thereby reducing grain yield. In the northern Guinea savanna of Nigeria, ICSV 111 was predisposed to high levels of anthracnose and grain mould when sown in early June and the first week of July (Marley, 2004).

Therefore it is advisable to sow these cultivars late in the season to coincide with period of reduced rainfall for better grain yield. KSV 8 and the local check produced the highest grain yields when sown on July 7 and their yields decreased subsequently as sowing date was delayed. At the first sowing date KSV 8 produced a significantly higher grain yield than the other cultivars. Early planting provided the opportunity for this late maturing cultivar to make use of the full growing season. Although KSV 8 had the highest *Striga* infestation (25.4 plants m^{-2}) on July 7 sown treatment, it produced 76 to 99% more grain than the other cultivars sown on that date (Table 2). This suggests that KSV 8 was tolerant to *Striga* infestation since it supported more *Striga*. When sowing was delayed by either one or two weeks, ICSV 111 followed by KSV 8 produced more grain than ICSV 400 and HANUNGIWA. The two cultivars, ICSV 111 and ICSV 400, either resisted or escaped *Striga* attachment, since they matured earlier, and thus supported significantly less emerged *Striga* than KSV 8 and the local cultivar. The lowest grain yield was obtained from the local cultivar which was 51% lower than the average grain yield of the improved cultivars. The local cultivar therefore has low genetic potential for grain yield, or is less tolerant of *Striga* infestation than the improved cultivars. Grain yield was inversely and significantly correlated with number of emerged *Striga* in both years (2005: $r = -0.44$, $P = 0.0020$, $N = 48$; 2006: $r = -0.47$, $P =$ 0013, $N = 48$).

Sorghum shoot dry weight

Sorghum shoot dry weight was affected by year, sowing date and cultivar. The 2- and 3-way interactions among year, sowing date and cultivar were significant (Table 1) because cultivars responded differently to sowing date and year (Figure 2). Sorghum shoot dry weight was lower in 2005 (Figure 2a) than in 2006 (Figure 2b). This may be attributed to the higher *Striga* infestation in 2005 (18.7 ± 2.20 m^{-2}) than in 2006 (5.1 ± 1.06 m^{-2}). Shoot dry weight was negatively and significantly correlated with *Striga* count in 2005 ($r = -0.50$, $P = 0.0003$, $N = 48$) but not in 2006 ($r = 0.15$, $P = 0.3243$, $N = 48$). In 2005, shoot dry weight did not reduce significantly with delay in sowing of each cultivar (Figure 2a). In 2005, shoot dry weight was also poorly correlated with sowing date ($r = -0.08$, $P =$ 0.6041, $N = 48$). However, ICSV 400 produced significantly higher shoot dry weight than all the cultivars when sown on July 7 or July 21 and produced higher shoot dry weight than HANUNGIWA and KSV 8 when sown on July 28 in 2005. In 2006, shoot dry weight of HANUNGIWA, ICSV 111, and KSV 8 was significantly higher when sorghum was sown on July 7 (Figure 2b). Shoot dry weight of HANUNGIWA (late maturing) and KSV 8 (medium maturing) decreased linearly as sowing date was delayed (Figure 2b). These two cultivars which are late and medium maturity performed poorly under delayed planting, probably because of moisture stress in October. Rainfall is less in the Sudan savanna where late sowing of late maturing cultivars may predispose the crop to late season drought thereby causing a reduction in crop yield. The shoot dry weight of ICSV 400 was not affected significantly by sowing date, the shoot dry weight of ICSV 111 did not differ significantly among sowing dates later than July 7. When sowing was delayed by (a) 3 or (b) 4 weeks, shoot dry weight (t/ha) was reduced in HANUNGIWA by (a) 1.55 and (b) 2.51, in ICSV 111 by (a) 1.57 and (b) 1.54, in ICSV 400 by (a) 1.29 and (b) 1.27, and in KSV 8 by (a) 1.43 and (b) 1.74 respectively. Shoot dry weight was negatively and significantly correlated with sowing date ($r = -0.60$, $P = <0.0001$, $N =$ 48). Shoot dry weight was positively and significantly correlated with grain yield in 2006 ($r = 0.44$, $P = 0.0020$, $N = 48$) but not in 2005 ($r = 0.24$, $P = 0.0987$, $N = 48$).

Striga hermonthica density

ANOVA detected significant year, sowing date and cultivar effects on number of emerged *Striga* plants (Table 1). All the two 2-way interactions between year, sowing date, and cultivar were not significant. The number of emerged *Striga* plants was 3.7 times higher in 2005 (18.7 ± 2.20) than in 2006 (5.1 ± 1.06). This may be attributed to heavier rainfall as weekly rainfall distribution was generally higher in 2006 than in 2005. In addition, the length of the period with sufficient rainfall was shorter in 2005 than in 2006. Rainfall started four weeks later in 2005 (1st week of July) whereas in 2006 rainfall it started in first 1st week of June. This trend agrees with earlier reports that *Striga* thrives on low rainfall or moisture stress and that continuous wet periods are unfavourable to its development (Shank, 1996). Odhiambo and Ariga (2004) reported low *Striga* infestation during the long rains in Kaura, Kenya. This was attributed to high soil moisture content for an extended period, causing *Striga* seeds to undergo wet dormancy.

After early sowing the number of emerged *Striga* plants was twice the total found when sowing was delayed by 21 or 28 days (Figure 3a). A similar effect on sorghum was reported by Lagoke et al. (1991) and on maize by Parker and Riches (1993) and Dugje et al. (2008). Gbèhounou et al. (2004) and Dugje et al. (2008) attributed

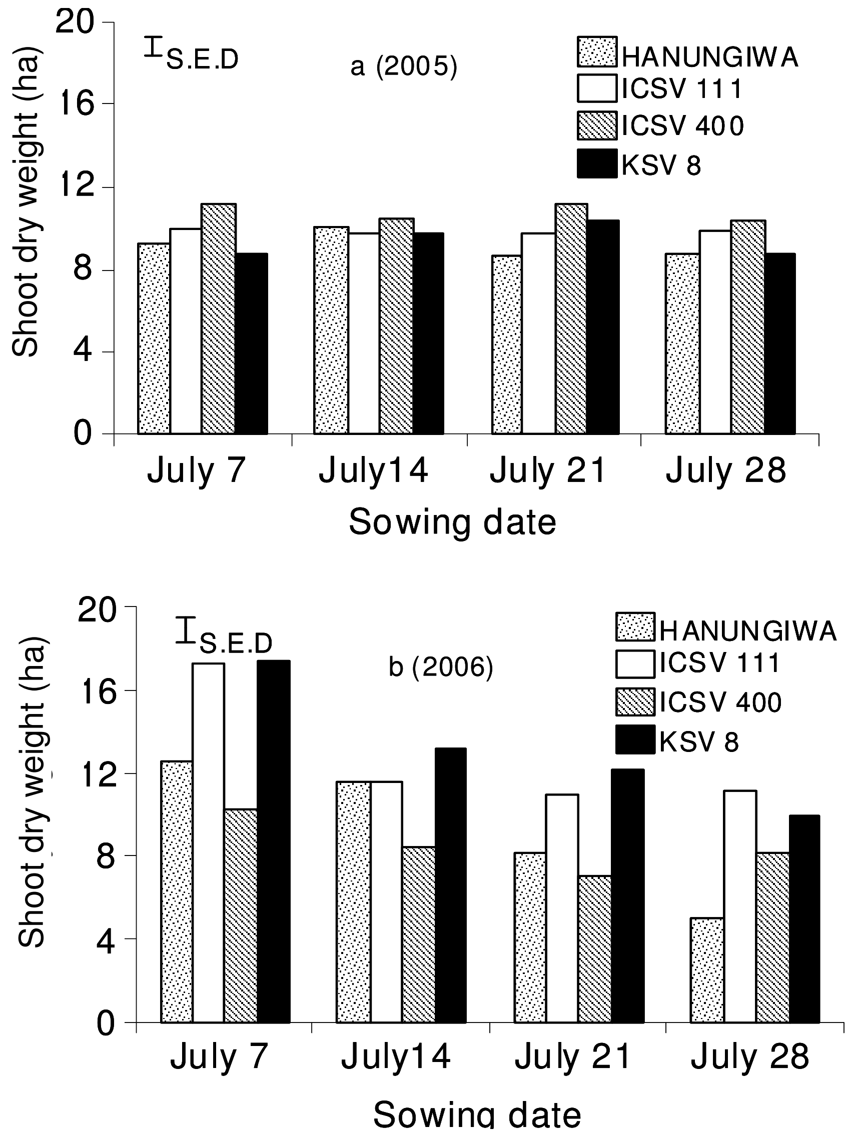

Figure 2. Effect of sowing date and sorghum cultivar on shoot dry weight (t ha^{-1}) in 2005 (a) and 2006 (b) in Nzuda, Borno State, Nigeria (S.E.D = Standard error of the difference between two treatment means).

higher infestation of *S. hermonthica* in early plantings to the ability of the host to produce more stimulants which encourage *Striga* seed germination and haustoria attachment. When planting is delayed *Striga* seeds are unable to germinate and seedlings fail to attach to host root systems due to unfavourable low soil temperatures during the middle of the rainy season (Hoffmann et al., 1997; Odhiambo and Ariga, 2004). Crop root exudates may also be leached following heavy showers, which would reduce *Striga* germination later in the season (Gbèhounou et al., 2004).

Averaged across year and sowing date, ICSV 111 and ICSV 400 had 25 to 110% fewer *Striga* than KSV 8 and HANUNGIWA (Figure 3b). The cultivar, KSV 8 had the highest number of emerged *Striga* plants, which did not differ significantly from that of the landrace (Figure 3b). The two cultivars ICSV 111 and ICSV 400 have short stature and mature earlier than KSV 8 or HANUNGIWA. Lower *Striga* counts in varieties with short growth cycles were reported by Oswald and Ransom (2004) for maize and by Dugje et al. (2003) for millet. Ransom and Odhiambo (1995) attributed low *Striga* population in small stature and early maturing maize genotypes to the production of less extensive root systems which provided fewer sites for *Striga* parasitism. The early maturing sorghum varieties may have escaped *Striga* parasitism and supported less *Striga* emergence from the combined effect of reduced stimulant production and unfavourable soil environment for *Striga* seed germination and haustorium attachment later in the season.

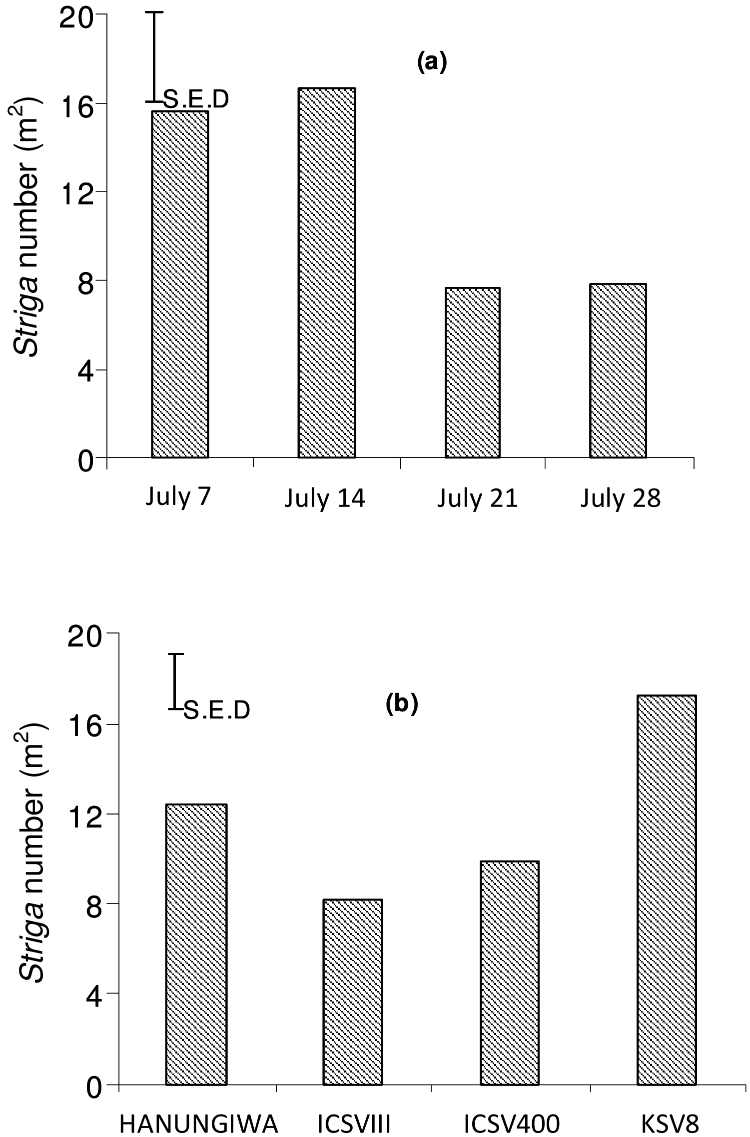

Figure 3. Effect of sowing date (a) sorghum cultivar (b) on number of emerged *Striga* plants (m^{-2}) in Nzuda, Borno State, Nigeria. Analysis was based on transformed data. Means are presented as original data. Values represent two year mean. (S.E.D = Standard error of the difference between two treatment means).

Conclusion

The period of rainy season in the Sudan savanna spans from June to the end of September (120 days). The beginning and end of the growing season are mostly unpredictable with the occurrence of early season and end of season droughts. Delay in sowing, therefore, result in a drastic reduction in yield due to a decrease in capture and conversion of crop growth resources as dictated by the rainfall events and duration of the growing season. There is, therefore, less opportunity for manipulating sowing dates for *Striga* control in the region. However, farmers can reduce *Striga* infestation by sowing *Striga* tolerant and medium maturing sorghum cultivars, such as KSV 8, between the first and second weeks of July, or by sowing early maturing and short stature sorghum cultivars, such as ICSV 1111 and ICSV 400, in the fourth week of July.

ACKNOWLEDGEMENTS

The authors would like to thank the Canadian International Development Agency (CIDA) for funding the Project, Promoting Sustainable Agriculture in Borno State (PROSAB) and sponsoring this study. The field technicians at IITA/PROSAB are acknowledged for managing the research fields and R. Umelo for editorial assistance.

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