African Journal of Food Science and Technology (ISSN: 2141-5455) Vol. 3(8) pp. 168-175, October 2012
Available online http://www.interesjournals.org/AJFST

Full Length Research Paper

Canopy structure weeding frequency plant density on weed and tuber yield of sweet potato (*Ipomoea batatas* L.), Awassa, southern Ethiopia

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Accepted 10 May, 2012

Sweet potato is either left unweeded or weeded lately in southern Ethiopia. The study was conducted to evaluate the effect of canopy structure, plant density and weeding frequency on weed infestation and tuber yield during 2002and 2003 Three sweet potato varieties with different growth habit [‘TIS 1499’,’TIS 2498’ and ‘Koka 6’], four plant densities [5, 7, 10, and 12.5 plants m^{-2}], and two weeding frequencies [Weeding once, 30-40 days after sprout (DAS) (W1), and twice 30-40 and 70 DAS (W2)] were laid out in factorial arrangement in randomized complete block design with three replications.The major weeds were broadleaf, grass and sedge. Weed density in 2002 was 54.5% less while weeding ‘TIS 1499’ and ‘Koka 6’ twice reduced weeds by 31.9 and 31.2%, respectively, but no significant variation in ‘TIS 2498’. The dry weed biomass in ‘TIS 2498’ and ‘Koka 6’ was 48.3 and 29.2% less, respectively. The yield in 2002 was 30.8% higher whereas the yields of ‘TIS 1499’ and ‘TIS 2498’ were not significant in both years. Weeding twice significantly produced 68.9% more yield of ‘TIS 1499’, but no significant variation between weeding practices in other varieties. The yields of ‘TIS 1499’ and ‘Koka 6’ within a population of 7 to 10 plants m^{-2} were significantly high, but ‘TIS 2498’ showed no significant variation among plant densities. The cultivar with spreading growth reduced weed infestation and required only one weeding, while that with erect growth needed two weedings. Plant density of 7 to 12.5 plants m^{-2} can be used for cultivars with erect and intermediate growth. Growth with spreading canopy can be used as means to reduce weed infestation that saves farmers’ time and labor. Breeders can thus focus in developing cultivars with spreading canopy with high yield.

Keywords: Growth habits, plant density, sweet potato, weed density, weed infestation.

INTRODUCTION

Sweet potato is one of the major horticultural crops widely grown in the Eastern and Southern regions of Ethiopia. At the national level, sweet potato occupies more than 53,000 ha of land with a total annual production of 4,507,628 million quintals with an average productivity of 8.43 t ha^{-1} (CSA, 2010). It is mostly adapted to moisture stress areas, and grows in the lowland and mid altitude areas of the southern region of Ethiopia occupying more than 29,523.93 hectares of land in the *meher* season (CACC, 2006; CACC, 2003a). It is grown both in *belg* (small rainy season from Feb to May) and *meher* (big rainy season from June to Sep*)* seasons covering large hectares in *meher w*ith the productivity of 8.68 t ha^{-1}. The report shows that sweet potato shares 34.1% of the total area and 36.8% of the total regional volume of root crop production (CACC, 2003b). It is indicated that 11.5% of the regional root crop area was grown with sweet potato resulting in 5.12% of the regional root crop production in belg.

Productivity is attributed to low yielding cultivars; weed competition, low or high population density, low rate or no application of fertilizer, and insect pests such as sweet potato butterfly and virus such as feathery mottle virus (SPFMV).

On station recommendation shows that a population of 33,000 to 56000 plants ha-1 produced an optimum tuber yield whereas farmers in southern Ethiopia use nearly 80,000 plants ha-1 (personal assessment, 2002 and 2003. According to Ambe (1995), higher plant density (20,000 plants ha-1) of sweet potato, which is accompanied by higher tuber yield, resulted in lower weed density whereas a plant density of 10,000 plants ha-1) sweet potato had more weed incidence and reduced yield because of weed competition.

Weeds compete with sweet potato for light, water, and nutrients, and may harbor a number of pests, including insects, nematodes, and diseases such as virus (Eberlein et al., 1994; Murray et al., 1994). Weed competition can reduce yield and quantity of sweet potatoes, affecting tuber size, weight, and quantity. Weeds interfere with harvest, causing more sweet potatoes to be left in the field and increasing mechanical injury. According to CACC (2003b), weeds account for 11.64% of the total damages of sweet potato production. A yield loss of 87 to 98.9% was recorded if sweet potato is left unweeded; even early or late weeding reduced the yield (Awassa productivity is attributed to low yielding cultivars; weed competition, low or high population density, low rate or no application of fertilizer, and insect pests such as sweet potato butterfly and virus such as feathery mottle virus (SPFMV).

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Cultivars differed in their sensitivity to weed competition. A study indicated that genotypes (varieties) with different growth habit and plant density did not show a significant effect on weed infestation; however, weeding frequency reduced weed growth (Tenaw *et al*., 1997).Similarly, Tenaw *et al*. (2011) reported that weed density in cultivars with spreading growth habit was significantly reduced by 17 and 18% compared to the cultivars with erect and intermediate growth habit. In contrary, Taye and Tanner (1997) reported some varieties to better compete and suppress weeds due to their canopy structure. Variety difference showed that one variety was more suppressive than the other due to the different growth habit (leaf area, number of tillers, plant height, canopy structure and development). According to ICARDA's (1984) report, because of differences in growth habit, the local wheat cultivar without weed control was superior to the improved cultivar in suppressing weed growth. The report further noted that seed rate significantly suppressed weed growth at two locations while lower seed rate showed higher weed dry matter. This study also showed that the local durum wheat cultivar was more competitive than the improved variety, which was indicated by the interaction of weed by variety on grain yield. The abovementioned study also noted more grain yield as plant density increased due to suppression of weeds by seed rate. Weed infestation tended to increase with decreasing seed rate and in the lower seed rate weed infestation was more. Salonen (1992) in his study indicated that crop density had no significant effect on weeds emerged but later the seed rate improved the competitive ability of both wheat and barley. Also, hand weeding was more effective than chemical weed control and increased grain yield of wheat particularly at lower seed rates (ICARDA, 1984).

According to the review of Harrison and Peterson (1994) on allellopathic effect of sweet potato, decaying sweet potato tissue inhibited alfalfa, cowpea and yellow nutsedge growth, and residues of sweet potato impairing the uptake of Ca, Mg, and S by cowpea. In the southern region of Ethiopia, sweet potato is left unweeded or weeded lately because of more emphasis to other crops (mainly cereals and pulses) and shortage of labor and time due to multiple cropping in one farm. Also, farmers assume that sweet potato is a better competitor with weeds because of its growth habit thus can perform better than other crops. So far, information regarding the effect of plant density, canopy structure, and weeding frequency on sweet potato is not available to the producers. Thus, the objective of this study was to investigate the effect of canopy structure, plant density and weeding frequency on weed infestation and tuber yield of sweet potato.

MATERIALS AND METHODS

Site description

The experiment was conducted at Awassa located at an altitude of 1700 masl. It has two growing seasons, *belg* (small rainy season from February to May) and *meher* (big rainy season from June to September). The rainfall is bimodal with a long-term mean rainfall of 1021 mm, and about 36.4 and 51.3% is received from February to May and June to September, respectively. The long-term mean maximum and minimum temperatures, May to September, vary between 24 and 27^0C and 12.8 and 13.8^0C, respectively. The soil of the experimental site was silt loam with pH of 7.0 (1:2.5 soil/water by weight/volume), total N: 1.90 mg kg^{-1}), available P: 57.24 mg kg^{-1}, and CEC, exchangeable K, Mg and Ca of 23.40, 3.25, 2.39 and 10.53 cmole kg^{-1} soil, respectively, and classified as Eutric fluvisol with silt loam texture.

Treatments and experimental design

Three recommended cultivars of sweet potato with different growth habit/canopy structure 'TIS 1499' erect/vertical growth and, short vine with low vegetative growth and early maturing; 'TIS 2498' spreading/, long vine with high vegetative growth, and early maturing; and 'Koka 6' an intermediate with medium vegetative growth and medium maturing], four plant densities [5, 7, 10, and 12.5 plants m^{-2}], and two weeding frequencies/practices [W1-one time weeding 30-40 days after sprout (DAS), and W2-weeding twice 30-40 and 70 DAS recommended] were used. Plant density was arranged by varying row spacing (1.0, 0.7, 0.5, 0.4 m) and maintaining plant spacing constant (0.20 m). Factorial arrangement in randomized complete block design with three replications was laid out with a gross plot size of 4m wide by 2m long.

Crop management

Planting dates were July 21, 2002 and June 12, 2003. The land was plowed with tractor. Fertilizer was applied at planting at the rate of 100 kg ha^{-1}(18 kg N and 46 kg P_2O_5 ha^{-1}) DAP (diammonium phosphate) as source of fertilizer.

Data collection and statistical analysis

Data on weed types and density (determined by counting all weed species in 0.25m by 0.25m quadrat per plot), weed dry biomass (above ground weed biomass was collected), which was sun-dried for 10 continuous days and weighed, plant population at harvest, and root yield were collected. Analysis of variance was conducted using SAS statistical package (SAS, 2000) and Tukey test of significance to differentiate treatment means. Because of the interaction effect of years with variety and plant density, combined analysis over years was conducted after test of homogeneity (Gomez and Gomez, 1994). Log transformation was made for weed infestation and tuber yield of sweet potato to stabilize the variances. Correlation and stepwise multiple regression analysis were carried to see the association between yield and related parameters and season, and find the contribution of the factors under study to the yield of sweet potato.

RESULTS

Effect of rainfall variation

In both growing seasons of 2002 and 2003, rainfall prevailed in 41.8% and 47.7% of the time, respectively (Table 1). Before planting in July 21, 2002, there was 160.7 mm of rain in the first two decades of June with few dry spells, which left residual soil moisture for the next planting. After vegetative growth, there was better rainfall in 48.4, 54.8, and 60% of the time in July, Aug, and September of 2002, respectively. Also, there prevailed heavy rainfall (varied between 13.8 and 51.9 mm) from August to September of 2002, which caused temporary water logging that might have affected vegetative growth of sweet potato. In 2003, rainfall prevailed in 46.7, 45.2, 51.6 and 70% of the time in June, July, Aug, and September, respectively. Heavy rainfall (ranging from 13.2 to 108 mm) prevailed in the first two decades of June that again created temporary water logging causing

Table 1 Amount of rainfall (mm) during the growing seasons of 2002 and 2003 and the long-term (1972-2006), Awassa

Month	2002	2003	Long-term (1972-2006)
June	114.6	277.7	108.5
July	174.1	147.1	135.4
August	154.8	112.6	138.9
September	183.9	161.2	141.2
October	40.3	58.5	83.1
Total	667.7	757.1	607.1

numbers in parenthesis are percent of the long-term rainfall

Table 2 Combined analyses of variance (ANOVA) over seasons on the effects of weed control, variety, and plant density on plant population at harvest, Awassa

Source of variation	Weeds m^{-2}	Plant density at harvest (no $plot^{-1}$)	Tuber yield (kg ha^{-1})
Year (Y)	**	**	**
Weeding (W)	**	**	**
Variety (V)	*	Ns	**
Plant density (Pd)	Ns	**	**
YW	**	Ns	**
YV	Ns	Ns	**
YPd	Ns	Ns	Ns
WV	**	Ns	*
WPd	Ns	Ns	Ns
VPd	ns	ns	*
WVPd	ns	ns	Ns

poor vegetative growth resulting in low tuber yield.

Weed types

A number of weed species were prominent throughout the study seasons. The major weeds in the experimental field were broadleaf, grass and sedge (Table 3). The dominant weeds were *Galinsoga parviflora, Ageratum conyzoides and Nicandra physalodes* covering 36.2, 20.8 and 10% of the total weeds in the experimental field, respectively.

Weed density

Effect of weeding was dependent on variation in seasons and variety (Table 2). The density of weed in 2002 with two hand weedings was 59% less; but significant variation between weeding practices was not observed in 2003 although more weeds were observed (Table 4). Weed population of the 2003 in one and two weedings in comparison with the 2003 was 33.7 and 73.9% less, respectively, with an overall reduction of 54%. On the other hand, effect of weeding on weed density was variable from one variety to the other. Weed population in

Table 3 Major weed types observed during the experimental seasons/years

Weed types	Average weed density (no .m^{-2})
Broad leaf	
Galinsoga parviflora	47
Ageratum conyzoides	27
Nicandra physalodes	13
Guizotia scabra	11
Leucas martinicensis	7
Amaranthus hybridus	6
Tagetes minuta	6
Argemone mexicana	4
Sedge	
Cyperus rotundus	5
Grass weed	
Eragrostis aspera	4

Table 4 Effect of weeding frequency and variety on weed population, and weed biomass

Year/season	Weeding frequency: W1	W2	Weed biomass (kg m^{-2})
	Weed population (no.m^{-2})		
2002	114 b	47 c	W1 0.97a
2003	172 a	180 a	W2 0.35b
Variety			
TIS 1499	165 a	112 c	0.89 a
TIS 2498	128 b	134 b	0.63 ab
Koka 6	137 b	93 c	0.46 b

W1 and W2-weeding once and twice, 30-40, and 30-40 and 70 days after sprout, respectively; Same letter in a treatment and trait show no significant difference at 5% probability level

each of 'TIS 1499' and 'Koka 6' when weeded once was significantly 47.3% more whereas the variation between weeding practices in the cultivar 'TIS 2498' was not significant.

Weed biomass

Weed biomass was significantly affected by variation in variety (P<0.0001) and weeding frequency (P=0.0008). The weed dry matter in 'TIS 2498' and 'Koka 6' was 29.2 and 48.3% less than that in 'TIS 1499', respectively (Table 4). Weeding twice reduced weed biomass by 63.9% compared to one weeding.

Plant density

Effects of season, weeding and plant density significantly affected plant population at harvest (Table 2). Plant population at harvest was 20.2% more in 2002 while two times weeding had more harvestable plants (13.8%) compared with one time weeding (Table 5). On the other hand, the last two plant densities (100 x 10^3 and 125 x

Table 5 Effect of season, weeding and plant density on plant population at harvest, Awassa

Year/Season	Plant density at harvest (no plot^{-1})
2002	36.3 a
2003	30.2 b
Weeding frequency	
One time	31.1 b
Two times	35.4 a
Plant density (no.ha^{-1})	
50 x 10^3	18.5 c
70 x 10^3	29.9 b
100 x 10^3	38.6 a
125 x 10^3	46.0 a

The same letter in each treatment show no significant difference at 5% probability level

Table 6 Interaction effect of variety with season, weeding frequency and plant density, and season with weeding on tuber yield of sweet potato (t ha^{-1})

Year/Season	Variety			Season	
	TIS 1499	TIS 2498	Koka6	2002	2003
2002	17.0 a	8.11 b	22.11 a		
2003	19.38 a	11.65 b	5.07 c		
Weeding frequency					
One time	13.53 b	8.63 c	13.22 c	15.1 ab	8.48 c
Two times	22.85 a	11.12 c	13.96 bc	16.37 a	15.58 a
Plant density (no. ha^{-1})					
50 x 10^3	13.29 c-f	11.44 d-f	9.85 ef		
70 x 10^3	19.42 ab	9.45 d-f	13.99 b-f		
100 x 10^3	18.38 a-c	9.70 f	14.93 b-e		
125 x 10^3	21.67 a	9.56 ef	15.57 b-d		

The same letter in each treatment show no significant difference at 5% probability level

10^3 plants ha^{-1}) had more plants at harvest and showed no significant variation between them.

Tuber yield

Analysis of variance showed that effect of weeding was dependent on seasonal variation (Table 2). In 2002, yield variation between weeding practices was not significant despite 8.4% increase when weeded twice. The yield in 2003 was significantly more (83.7%) with two weedings whereas the yield in 2002 was 30.8% higher than the 2003 (Table 6) The response of varieties to the different seasons was different, and ‘TIS 1499’ and ‘TIS 2498’ showed no significant difference between years, but ‘Koka 6’ produced significantly more (336% increase) in

2002 over the other year. The mean yields of 'TIS 1499' and 'Koka 6' were 84.1 and 37.6% higher than 'TIS 2498', respectively.

Effect of weeding on tuber yield was dependent on varietal growth of sweet potato. The variety with vertical and low vegetative growth having short vine with early maturing character yielded 68.9% more when weeded twice (Table 6). Weeding twice also increased the yields of 'TIS 2498' and 'Koka 6' by 28.9 and 35.5%, respectively, although variation between weeding practices was not significantly variable. Also, significant variation on tuber yield was observed among plant densities. There were a 23.9, 22.5, and 35.3% yield increase as plant density increased from 5 to 7, 10 and 12.5 plants m^{-2}, respectively. However, the yields of 'TIS 1499' and 'Koka 6' were higher within the population of 7 to 12.5 plants m^{-2} while the yield of 'TIS 2498' did not show significant differences among the various plant densities.

DISCUSSION

The major weeds during the experimental years were broadleaf, grass and sedge, broadleaf being the dominant covering 94% of the total weeds. Weed infestation was influenced by variation in season in which poor distribution of rainfall in 2003 (29 and 13.4% more rain than the long-term and 2002, respectively), caused temporary water logging and dry spell at vegetative growth stage, and this contributed more to high weed infestation (117.3% more than 2002). The work of Wicks *et al*. (1999) showed that weed biomass varied with season because of high rainfall in one season than the other, which is in line with the result of the current study. The negative association between weeding frequency and weed population (r = -0.216**) showed that removal of weeds twice significantly reduced weed density (20.3% less with two weedings).

Variation in weed infestation among sweet potato varieties was because of differences in canopy structure. Low weed population and weed biomass in 'TIS 2498' (5.7 and 48.3% less, respectively, than the erect variety) was because it is spreading with long vine and high vegetative growth, and showed that varieties with these characters could better compete with weed because of no response to frequency of weeding, and need only one weeding while those with erect, short vine and low vegetative growth need weeding twice, which was attributed to variation in canopy structure. It also showed that varieties with short vine having vertical and low vegetative growth are prone to weed infestation. This implies that varieties with spreading, long vine, medium as well as high vegetative growth can better compete with weed, and suppress weed growth through competing for nutrients, soil moisture and light interception. Both Levett (1992) and Conley *et al*. (2001) also reported the effect of cultivars on weed suppression.

The low weed population in 'TIS 2498' might probability be canopy closure was faster that contributed to better competition for light, moisture, and nutrient (Olofsdotter *et al*., 1999) and thus hindering light interception by weeds. In addition, probably the higher leaf area of 'TIS 2498' might have suppressed weed growth by hindering light transmittance to the ground thus lower weed population (Tenaw *et al*., 2011; Seavers and Wright, 1999; Teasdale, 1995). In contrary, varieties with erect growth needed twice weeding because of a 31.9% reduction in weed population. In line was the finding of Tenaw *et al* (2011) that indicated varieties with spreading canopy structure reduced weed infestation while the erect types were infested with weed. The non-significant effect of plant population on weed density could probably be attributed to less competition at the lower than higher plant density and led to better crop growth. In line is the work of Conley *et al*. (2001) that stated decreasing row spacing did not provide a competitive advantage for potatoes as measured by vine or tuber biomass or tuber yield. In contrary, other findings showed reduced weed interference as plant density increased through hindering light interception.

Difference in seasons resulted in variation in tuber yield of sweet potato due to differences in amount and distribution of rainfall during the growing periods, and this resulted in a 23.6% reduction in tuber yield in 2003 compared with the 2002 season. The variety with vertical and low vegetative growth having short vine with early maturity produced 68.9% more tuber yield when weeded twice while variation between weeding practices on tuber yield of 'TIS 2498' and 'Koka 6' was not significant indicating varieties with spreading and intermediate growth habit could be weeded only once despite a 28.9 and 5.6% increase over one weeding, respectively. More tuber yield of sweet potato was also attributed to frequency of weeding (r = 0.228**), plant density (r = 0.271**), and plant population at harvest (r = 0.393**). Similarly, Tenaw *et al* (2011) also reported the positive effect of plant density on tuber yield of sweet potato. Plants m^{-2} at harvest was negatively affected by season (r = -0.206*) but positively increased with increase in plant density (r = 0.679**). In 2003, because of lower seedling emergence, plant population at harvest was 16.8% less than the other year, and this significantly affected tuber yield of sweet potato. The finding of Tenaw *et al*. (2011) showed seasonal effect on the effects of weeding, variety, and plant density on crop growth and tuber yield.

CONCLUSION

Frequency of weeding and the variety with spreading canopy structure with long vine and high vegetative growth reduced weed population. On the other hand, varieties with erect and short vine with low vegetative growth were highly infested with weed. The finding indicates that those varieties with erect and low vegetative growth can be weeded twice to reduce weed infestation and increase crop yield. The use of varieties with spreading and long vine, and use of an optimum plant density can potentially reduce weed infestation and the cost of weed control. Overall, weed suppression can be achieved through the use of varieties with spreading type, and this can be exploited as a strategy to reduce weed infestation and increase tuber yield of sweet potato. Thus, breeders should focus in developing varieties with spreading canopy structure for reducing weed infestation and increase crop yield.

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