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Corn-stalk lodging and borer damage as influenced by varying corn densities and planting geometry with soybean (*Glycine max*. L. Merrill)

B.C. Echezona

Department of Crop Science, University of Nigeria Nsukka, Nigeria

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A b s t r a c t. Cultural practices which increase the amount of insect pressure can also increase the amount of lodging that occurs in the corn crop. Studies were therefore carried out, in the late cropping seasons of 2002 and 2003, on the effect of corn planting densities and geometry with soybean on corn lodging and infestations by stem borers. Treatments comprised three corn population densities of 40 000, 60 000 and 80 000 plants ha^{-1} and three geometrical arrangements of corn-soybean mixtures of 1:1, 1:2 and 1:3, in all possible combinations. There were also three sole crop populations of corn and one of soybean. This resulted in 13 treatments which were laid out in field plots in a Randomized Complete Block Design (RCBD) with three replications. Results of the studies showed that increasing corn population significantly ($P<0.05$) increased corn-stalk lodging and plant height, but significantly reduced the stalk diameter, shoot dry weight and infestations and damage by borers on corn, as well as the grain yields of corn and soybean. This is such that plants at 80 000 stands ha^{-1} recorded the highest amount of lodged stalks and the tallest plants, but the least stalk girth, shoot dry weight, infestation and damage by corn borers. The lowest grain yield was also obtained at this density. Differences in geometrical arrangements of corn-soybean and its interaction effects with planting density among these parameters did not attain any level of statistical significance. Similarly, the effect of intercropping corn with soybean did not produce any significant result on corn with respect to these parameters. These results are discussed in the light of corn planting densities and geometric arrangements with soybean, on corn production.

K e y w o r d s: stalk lodging, borer damage, planting densities, planting geometry, soybean

INTRODUCTION

Corn, *Zea mays* L. and soybean, *Glycine max*. L. Merrill, are two crops that can be grown together under intercropping system. Intercropping is an age-old practice in tropical and sub-tropical Africa. It has been widely accepted because it provides the farmer with insurance against unpredictable crop failures, especially by pests and diseases (Okigbo and Greenland, 1976). Association of corn and soybean in the field (Lampang, 1981) and in human nutrition (Anonynomus, 1986) has been quite commendable since in each case they appear to complement each other and are therefore adjudged to be of high compatibility.

Stalk lodging of corn has been described as a major problem of corn production (Hicks, 2004; Ransom, 2005). It was described as the breakage of the stalk below the corn ear (Nielsen, 2006). According to Ransom (2005), stalk lodging is a term used to describe the crop when its stem has partially or completely fallen over from their normal near-vertical orientation. Hicks (2004) reported that corn lodging is a stress on the corn plant. Ransom (2005) divided corn lodging into two major types. The first is root lodging which occurs at the base of the plant or at soil level when the roots fail to anchor the crop properly. The second is the stem lodging which occurs at any location on the stem above the prop root level. Both types of lodging are accomplished by the plant bending markedly from its usual upright position. On the effect of lodging on the plants, Hicks (2004) reported that lodged plants will likely yield lower and make harvesting more difficult. Ransom (2005) reported that yield losses as high as 40% could result from lodging. Annual yield losses due to stalk lodging in a technologically advanced country like the United States of America were estimated at between 5 and 25% (Nielsen, 2006). Up to 75% of the corn field could be devastated by stalk lodging (Van Dyk, 2001).

A number of factors have been identified to predispose crops to lodging. These factors are high levels of nitrogen, high seeding rates, excessive soil moisture, excessively tall varieties with poor straw strength, and strong wind (Ransom, 2005). In addition, Van Dyk (2001) reported that some

Corresponding author's e-mail: chezbon2001@yahoo.co.uk

fungi, like *eg* Anthracnose, in stalk rots could lead to stalk lodging, while poor root development, root worm damage and root rot could cause severe root lodging experienced in the United States of America. On the other hand, Nielsen (2006) noted that the paramount causes of lodging in Purdue is the European corn borer, particularly the second generation, which tunnels into the stalk or ear shank and can cause stalk breakage or ear droppage. In Nigeria, one of the major causes of corn lodging is the stem borer (Onwueme and Sinha, 1999; Hill and Waller, 1999; Youdeowei, 2004). The second generation of this pest bores into the shank or stem of the plant causing symptoms popularly referred to as dead heart (Hill and Waller, 1999). Boring by this insect into the stem disrupts the flow of nutrient fluids from the roots to the upper parts of plant and eventually weakens the stem. Affected plants are liable to collapse (lodge) with the slightest wind (Youdeowei, 2004). Experience has also shown that rot is not a major predisposing factor to lodging in Nigeria, although occasionally it is inoculated to the plant through the feeding activity of stem borers. This may be why Nielsen (2006) stated that the incidence and severity of stalk rot in any given field depended on the susceptibility of the corn hybrid, on the presence and virulence of stalk rot organisms, and on environment conducive to formation of the disease, all of which must be present simultaneously for the rot to develop. However, in either situation, the corn is placed under physiological stress which favours stalk lodging. In Nigeria, Youdeowei (2004) noted that termites constitute the major predisposing factor to root lodging.

In recent years, agricultural scientists involved in pest management have been using possible alternatives that will reduce excessive pesticide usage to maintain pest populations below economic threshold. These alternatives are focused on ecological knowledge which permits agro ecosystems management and manipulation. Agricultural activities which favour the penetration of light to the crop bases have been reported to influence the degree of resistance or vulnerability of plants to some insect attack (Freyman and Venkateswarlu, 1977; De *et al*., 1978; Singh, 1979; Nielsen, 2006). They reported that this influence could be achieved either through alteration of the physical strength of the plant or through altered distribution of carbohydrates between the stalk and the ear in favour of the ear (Williams *et al*., 1968; Nielsen, 2006). Evidence, however, abounds that such agricultural practices like alteration in planting densities and planting geometry are bound to affect pest fauna, and distribution as such practices is of paramount importance in the efficiency with which solar radiation is distributed at the crop bases (Freyman and Venkateswarlu, 1977; Singh, 1979; Funderburk *et al.*, 1993).

The objective of this study, therefore, was to study the potential of reducing corn lodging caused by stem borer attack through alteration of corn planting density and geometry with soybean, which hitherto had remained the normal agricultural practice of rural farmers.

MATERIALS AND METHOD

The experiments were carried out at the Teaching and Research Farm of Faculty of Agriculture, University of Nigeria, Nsukka. Nsukka is located at latitude 06°52’N and longitude 07°24’E with an altitude of 447.26 m above mean sea level. The studies were carried out for two years, during 2002 and 2003 late cropping seasons. The soil of the experiment site is a reddish-brown sandy clay loam Ultisol (Oxic Paleustult) belonging to the Nsukka series and formed in false-bedded sandstone parent material (Mbagwu, 1990).

Core soil samples were taken before the experiment from the experimental sites at 50 cm soil depth and bulked together for physical and chemical analyses. Some of the soil pertinent physical and chemical properties are summarized in Table 1. Results of the physicochemical characteristics of the soil show that the soil was a sandy clay loam, slightly acidic and with low organic carbon, nitrogen and exchangeable bases. The available phosphorus and base saturations were moderate.

The experimental sites were ploughed with a primary implement and later harrowed with a secondary implement. A total land area of 780 m^2 was marked out for each experimental period. The marked area was later divided into three blocks. Each block was divided into 13 plots to which the treatments were later assigned. Treatments comprised three corn densities of 40 000, 60 000, and 80 000 plants ha^{-1} and three planting geometries of corn/soybean mixture of 1:1, 1:2 and 1:3, in all possible combinations. There were also three sole crop populations of corn and one of soybean. This resulted in 13 treatments which were laid out in field plots in a Randomized Complete Block Design (RCBD) with three replications. The distance between two plots was one metre and between two blocks were two metres.

T a b l e 1. Some physical and chemical properties of the investigated soil of the 2002 and 2003 experimental sites

Properties	2002	2003
Sand (%)	72.00	72.00
Silt (%)	7.00	8.00
Clay (%)	21.00	20.00
pH($H_2$0)	5.35	5.40
pH(KCl)	4.85	4.80
Organic carbon (%)	0.77	0.65
Total N(%)	0.07	0.06
Exchangeable bases (meq / 100 g soil)		
Na	0.06	0.03
K	0.12	0.12
Ca	1.12	0.80
Mg	0.85	0.55
CEC	3.91	2.90
Available phosphorus	5.10	4.93
Percentage base saturation	54.50	52.40

The within-the-row spacing for corn was 25 cm and for soybean it was 5 cm. The various plant populations were obtained by using between-the-row spacing of 100, 70, and 50 cm for corn and 100 cm for soybean. To achieve the various cropping geometries (1:1, 1:2, 1:3 and sole populations of maize and soybean) under comparable populations, the between-the-rows spacing of the sole soybean was kept constant for 1:1, reduced by one half for 1:2 and by one third for 1:3. Conversely, the within-the-row spacing was kept constant with the sole, doubled and trebled, respectively. Random allocation of treatments was done using the Fisher and Yates table of random numbers.

Planting was done on a flat area. Corn variety Western Yellow (FARZ-7) and soybean variety TGX-579 were used for the experiment. The varieties are known to be high yielding, medium maturing and of high susceptibility to diseases and insect pests, particularly corn-stalk borer. Weeding was manual and was done three times before the completion of each experiment. Fertilizer was broadcast at the rate of 200 kg ha^{-1} of NPK (15:15:15) before planting. At the pod-set stage of soybean, 45 kg N ha^{-1} was applied as urea to all the plots. Other agronomic management practices were duly observed. The plots were allowed to be naturally infested with various insect pests and diseases. No insecticide was used to avoid undue interference into the natural populations of the insects and diseases.

Data collection

The plant heights of both corn and soybean were measured in centimetres. The measurements were accomplished using a metre rule. Corn height was taken as the height from the ground level to the ring mark at the base of the tassel. The height of soybean was taken as the height from the ground level to the tip of the apical bud. Stem diameters of 10 randomly selected corn stands from each plot were also measured and recorded. The stem diameters were commonly measured using a micrometre screw gauge. The diameter of corn was taken 10 cm above ground level, while the diameter of soybean was taken 5 cm above the ground level. The percentage of lodged corn stand per plot was also recorded at harvesting. Lodged stands were usually partitioned into root lodging (lodged from ground level) and stem lodging (lodged from any point above the ground level) before recording. At 100 DAP (day after planting), three corn plants were randomly selected from the central rows of each plot and severed from their bases with pruning shears, after taken their heights. The severed stands were visually assessed for entry/exit holes made by stem borers. Counts of these holes were later taken and converted to counts per 100 cm corn-stalk stand before recording. The severed stands were also later dissected with a dissecting knife and the entire stem borer larvae inside the stalk extracted and counted. The extracted larvae were also converted to count per 100 cm corn-stalk before recording. The 100 cm corn-stalk length was taken into consideration because of the variation that may arise due to differences in corn plant heights. At harvest, pods were shelled, winnowed and dried, and total grain yield (kg ha^{-1}), corrected to 15% moisture content, taken and recorded from 10 randomly selected plants of corn and soybean.

All the data collected were subjected to analysis of variance (ANOVA). Skewed distributions were transformed using appropriate transformation procedures before analysis of variance was carried out on them. Both the mean values and the standard errors of the difference between treatment means were calculated according to the standard procedure.

RESULTS

Stem lodging

Increase in the corn populations from 40 000 to 80 000 plants ha^{-1} resulted in a significant ($P<0.05$) increase in stem lodging (Table 2). This is such that plots with 80 000 corn plants ha^{-1} significantly ($P<0.05$) produced higher lodged corn-stalks (5.4%) when compared with plots with 60 000 and 40 000 corn plants ha^{-1} (5.4 and 5.2%, respectively) in 2002. Similar results were obtained in 2003 with plots having 80 000 plants ha^{-1}, recording significantly higher ($P<0.05$) lodged stems (11.3%) when compared with plots planted at 60 000 and 40 000 corn plants ha^{-1} (4 and 3.6%, respectively). On the contrary, neither the planting geometry nor its interaction with planting densities produced any significant effect on stem lodging during the period. Furthermore, association of corn and soybean did not significantly affect stem lodging throughout the experimental period. In 2002 and 2003, the intercrop and sole plants had stem lodgings in the ranges of 8.7-8.9% (2002) and 6.3-8.2% (2003).

Insect infestations and damage

From samples taken at 50 and 100 DAP, the number of stem borer larvae extracted from corn-stalks were significantly ($P<0.05$) higher in widely spaced corn-stalks than in densely spaced stalks, irrespective of the geometric configuration of the plant and of soybean (Table 3). At 50 DAP, larval counts in 2002 from the 40 000 corn plants ha^{-1} plot (2) were significantly ($P<0.05$) higher than counts (1) from the 80 000 plants ha^{-1} plots, but similar to those from 60 000 plants ha^{-1} (1.6). In 2003, larval counts (2.4) from plots of 40 000 plants ha^{-1} were significantly higher ($P<0.05$) than counts from either 60 000 (1.9) or 80 000 plants ha^{-1} (0.8) in the same year. Also larval counts taken at 50 DAP showed that the planting geometry of the crops did not significantly influence the number of larvae on the corn-stalk. Consequently, the highest stem borer larvae numbers were obtained from corn-stalks arranged in 1:1 (1.7 larvae per 100 cm stalk), and the least in plants arranged in 1:2 (1.3 larvae per 100 cm stalk). Also samples taken at 50 DAP showed that association of corn and soybean had similar numbers of larvae (1.5) like sole corn (1.8). Similarly, the interaction of planting densities and geometric arrangement did not

T a b l e 2. Percentage stem and root lodging of corn per plot at 100 DAP as affected by cropping systems of corn and soybean during 2002 and 2003 late cropping seasons

Year	Cropping geometry (Corn: soybean)	Stem				Root			
		40 000	60 000	80 000	Mean	40 000	60 000	80 000	Mean
		(corn plants ha^{-1})							
		Corn + soybean							
2002	1:1	6.8	7.4	17.0	10.4	4.0	2.5	2.5	3.0
2003		3.2	1.8	15.2	6.7	6.5	3.2	5.0	4.9
2002	1:2	5.6	5.2	15.7	8.8	5.5	7.8	7.8	7.0
2003		7.1	0.7	2.0	3.3	2.9	8.7	6.6	6.1
2002	1:3	3.2	3.5	13.5	6.7	2.1	2.5	10.6	5.1
2003		1.5	3.4	5.0	3.3	4.4	8.7	4.5	5.9
		Mixture of corn/soybean							
2002	1:1, 1:2, 1:3	5.2	5.4	15.4	8.7	4.2	2.2	3.2	3.2
2003		3.6	4.0	11.2	6.3	4.6	6.9	5.4	5.6
		Sole corn (plants ha^{-1})							
2002		7.1	8.5	11.2	8.9	2.2	0.7	4.5	2.5
2003		7.2	7.5	9.9	8.2	8.9	8.0	3.5	6.8

	Stem 2002	Stem 2003	Root 2002	Root 2003
$S.E_{(0.05)}$ for comparing any:				
2 population means	4.0	2.61	NS	NS
2 planting geometry means	NS	NS	NS	NS
2 pop. x planting geometry means	NS	NS	NS	NS
$t_{(0.5)}$ for comparing intercrop and sole crop means	NS	NS	NS	NS

produce any significant effect with respect to larval counts taken at 50 DAP in 2002. The situation was similar in 2003. Also samples taken at 100 DAP in 2002 and 2003 followed a similar trend.

Entry/exit holes

The results of the number of entry/exit holes as affected by planting density and planting geometry are shown in Table 4. The results show that numbers of entry/exit holes were not affected by the geometric arrangements of corn and soybean. In 2002, the geometric arrangements had their corn-stalks with 9.0-10.5 entry/exit hole ranges. In 2003, 1:1, 1:2, and 1:3 arrangements had 13.4, 11.5 and 11.1 entry/exit holes on their corn-stalks, respectively. Decreasing corn planting densities, on the other hand, significantly ($P<0.05$) and progressively increased the number of entry/exit holes on corn-stalks throughout the experimental period. This is such that corn-stalks at 40 000 plants ha^{-1} possessed significantly ($P<0.05$) the highest numbers of entry/exit holes (15.3 in 2002 and 15.9 in 2003) compared with other higher planting densities. The planting density of 80 000 plants ha^{-1} recorded the least count (2.9 in 2002 and 4.0 in 2003). Neither the planting geometry nor its interaction with planting density had any significant influence on the number of entry/exit holes made on the corn-stalk by the pest. Corn intercropped with soybean had similar number of entry/exit holes to the sole corn in all the cropping seasons. The numbers of entry/exit holes made on intercropped corn-stalks were 9.8 in 2002 and 12.0 in 2003, while the numbers of holes made on the sole corn-stalk were 10.4 in 2002 and 11.9 in 2003.

Plant height

The results of the plant height as influenced by treatment combinations are presented in Table 5. In both 2002 and 2003, the geometric arrangement of the crops did not exert any significant influence on the plant heights of both

T a b l e 3. Number of stem borer larvae per 100 cm corn-stalk at 50 and 100 DAP as influenced by cropping systems of corn and soybean during 2002 and 2003 late cropping seasons

Year	Cropping geometry (Corn: soybean)	50 DAP				100 DAP			
		40 000	60 000	80 000	Mean	40 000	60 000	80 000	Mean
		(corn plants ha^{-1})							
		Corn + soybean							
2002	1:1	2.0	2.0	1.1	1.7	3.3	1.6	1.7	2.2
2003		2.7	1.7	0.7	1.7	4.2	2.7	0.9	2.6
2002	1:2	1.4	1.7	1.0	1.3	4.7	2.0	1.0	2.6
2003		2.4	2.0	0.9	1.8	2.4	2.3	2.0	2.2
2002	1:3	2.4	1.1	0.9	1.5	2.3	1.9	1.6	1.9
2003		2.1	1.9	0.7	1.6	3.3	0.9	1.6	1.9
		Mixture of corn/soybean							
2002	1:1, 1:2, 1:3	2.0	1.6	1.0	1.5	3.4	2.0	1.4	2.3
2003		2.4	1.9	0.8	1.7	3.3	2.0	1.5	2.3
		Sole corn (plants ha^{-1})							
2002		2.4	2.0	1.0	1.8	4.3	2.4	1.8	2.8
2003		2.9	2.4	1.1	2.1	2.7	1.9	1.2	1.9

	50 DAP		100 DAP	
	2002	2003	2002	2003
$S.E_{(0.05)}$ for comparing any:				
2 population means	0.48	0.57	0.64	0.50
2 planting geometry means	NS	NS	NS	NS
2 pop. x planting geometry means	NS	NS	NS	NS
$t_{(0.5)}$ for comparing intercrop and sole crop means	NS	NS	NS	NS

corn and soybean. The plant heights of corn and soybean in 2002 at the planting geometry of 1:1 were 155.4 and 84.0 cm, respectively, with a relative height difference between corn and soybean of 71.4 cm or 46%; whereas in 2003, the plant heights were 138.6 and 82 cm, respectively, in 1:1 arrangement. This resulted in a relative height difference of 56.6 cm or 40.8%. At planting geometry of 1:2, the heights of corn and soybean in 2002 were 154.3 and 84.1cm, respectively. This corresponded to a relative height difference of 70.2 cm or 45.5%. In 2003, the plant height of corn and soybean under 1:2 planting geometry were 131.5 and 81.6 cm with a corresponding height difference of 49.9 cm or 37.9%. The plant heights of corn and soybean in 2002 when row intercropped in 1:3 arrangement were 161.5 and 95 cm, which translated to a relative height difference of 66.5 cm or 41.2%; whereas, the plant heights in 2003 of 137.0 and 82.9 cm respectively resulted in a relative height difference of 52.8 cm or 35.4%. The plant height at 80 000 plants ha^{-1} were significantly ($P<0.05$) higher than the plant heights at any other lower densities. The plant heights at the two lower planting populations in turn did not differ from each other except for soybean in 2003 and corn in 2002. In 2002, the plant heights of corn and soybean at 40 000 corn ha^{-1} were 149 and 70.1 cm, respectively. This corresponded to a relative height difference of 78.9 cm or 33%: whereas in 2003 the plant heights were 127.8 and 75.1 cm, respectively, with a relative height difference of 52.7 cm or 58.8%. The heights of corn and soybean planted at 60 000 corn plants ha^{-1} in 2002 were 152.4 and 88.8 cm, respectively, with a relative height difference of 63.6 cm or 41.7%. In 2003, the plant heights were 137.1 and 77.5 cm, respectively, with a relative difference of 59.6 cm or 43.5%. Similarly the plant heights of corn planted at 80 000 plants ha^{-1} and soybean were 158.9 and 95 cm, respectively, in 2002 with a relative difference of 63.9 cm or 41.2%, whereas in 2003, the plant heights were 135.8 and 82.1 cm, respectively, with a relative difference of 53.7 cm or 60.5%. Generally, the heights of the sole crops did not differ significantly from their respective intercrops

T a b l e 4. Number of entry/exit holes of stem borer larvae per 100 cm corn-stalk as affected by cropping systems of corn and soybean during 2002 and 2003 late cropping seasons

Year	Cropping geometry (Corn: soybean)	40 000	60 000	80 000	Mean
		(corn ha^{-1})			
Corn + soybean					
2002	1:1	18.2	10.7	15.3	10.5
2003		21.0	15.1	4.0	13.4
2002	1:2	10.7	12.2	4.1	9.0
2003		18.5	12.0	4.1	11.5
2002	1:3	15.3	12.4	2.9	10.2
2003		15.9	13.3	4.0	11.1
Mixture of corn/soybean					
2002	1:1, 1:2, 1:3	14.7	11.5	3.4	9.8
2003		18.5	13.3	4.0	12.0
Sole corn (plants ha^{-1})					
2002		16.2	12.1	3.0	10.4
2003		17.0	14.4	4.4	11.9

	2002	2003
$S.E_{(0.05)}$ for comparing any:		
2 population means	0.59	1.89
2 planting geometry means	NS	NS
2 pop. x planting geometry means	NS	NS
$t_{(0.5)}$ for comparing intercrop and sole crop means	NS	NS

in all the years. Similarly, the combined effect of planting density and the spatial arrangement did not significantly affect the plant heights of the two crops, throughout the experimental periods.

Shoot dry weight and stem diameter

The results of the shoot dry weight and stem diameter of corn are presented in Table 6. Geometric arrangement of corn and soybean did not exert any significant influence on both the shoot dry weight (g plant^{-1}) and stem diameter (cm) of corn throughout the experimental periods. The highest shoot dry weight was produced by spatial arrangement 1:1 (91. 49 in 2002 and 95.8 g plant^{-1} in 2003), and the least by 1:2 (89.5 in 2002 and 88.1 g plant^{-1}in 2003). The corn stem diameters of 2.6, 2.5, and 2.6 cm, obtained by corn plants in 2002 in 1:1, 1:2 and 1:3 arrangements, did not differ significantly from one another. Similarly, corn diameters of 2.7 cm, 2.6 cm and 2.7 cm, obtained in 2003 when arranged in 1:1, 1:2, and 1:3, respectively did not attain any level of statistical difference, either. Conversely, the shoot dry weights and stem diameters in 2002 and 2003, for corn plants at 80 000 plants ha^{-1}, were significantly ($P<0.05$) lower than their corresponding shoot dry weights or stem diameter obtained from corn plants at lower plant populations of 60 000 or 40 000 plants ha^{-1} under comparable growing seasons. In 2002, the shoot dry weight ranged between 104.1 g plant^{-1} in 40 000 corn plants ha^{-1} and 68.9 g plant^{-1} in 80 000 corn plants ha^{-1}. In 2003, it ranged from 103.1 g plant^{-1} in 40 000 corn plants ha^{-1} to 71.1 g plant^{-1} at 80 000 corn plants ha^{-1}. Similarly, the stem diameter in 2002 ranged from 1.9 cm in 80 000 plants ha^{-1} to 3 cm in 60 000 plants ha^{-1}. However, in 2003, the stem diameter ranged from 1.9 cm in 80 000 plants ha^{-1} to 3.1 cm in 40 000 plants ha $^{-1}$. The shoot dry weight of the intercrops in 2002 and 2003 (90.5 and 91.5 g plant^{-1}, respectively) or their diameter (2.6 and 2.7 cm) did not attain any level of statistical significance with their corresponding sole crop shoot dry weight (90.3 and 88. 9 g plant^{-1}) or stem diameters (2.7 and 3.2 cm) in comparable experimental periods.

Grain yield

Table 7 shows the effect of cropping systems on the grain yield of corn and soybean. The highest corn and soybean grain yields were obtained at corn population of 60 000 plants ha^{-1}. The corn grain yield from 60 000 plants ha^{-1} in 2002 and 2003 (2276. 3 and 2276.5 kg ha^{-1}, respectively) was significantly ($P<0.05$) higher compared to the corresponding grain yields at 80 000 plants ha^{-1} for the same periods (1431.6 and 1534.9 kg ha^{-1}). However, the grain yields obtained from 60 000 and 40 000 plants ha^{-1} did not differ from each other significantly throughout the experimental period. Conversely, the grain yield of soybean when intercropped with corn at 40 000 plants ha^{-1} (1411.6 kg ha^{-1} in 2002 and 1318.6 kg ha^{-1} in 2003) was consistently and significantly ($P<0.05$) higher when compared to the grain yield produced when intercropped at either 60 000 plants ha^{-1} (1351.3 kg ha^{-1} in 2002 and 1294.4 kg ha^{-1} in 2003) or 80 000 plants ha^{-1} (1203.7 kg ha^{-1} in 2002 and 1117.4 kg ha^{-1} in 2003). However, the grain yields produced at 60 000 and 80 000 plants ha^{-1} during the experimental periods did not differ from each other. Both the planting geometry and its interaction with planting density did not attain any level of statistical significance in relation to grain yield during the experimental periods. Also the grain yields of soybean from sole crops and intercrops did not differ significantly throughout the experimental period.

DISCUSSION

In this study, higher population densities resulted in excessive stem elongation and lodging. Extremely high densities limit sunlight interception on the crop canopy, resulting in reduced photosynthetic activity. Explaining

Table 5. Heights of corn and soybean plants (cm) at 100 days after planting (DAP), relative height and percentage height difference between corn and soybean as affected by cropping systems of corn and soybean during 2002 and 2003 late cropping seasons

Year	Cropping geometry (Corn: soybean)	Plant height (cm) at 100 DAP								Corn and soybean							
		Corn				Soybean				Relative hight				Hight difference (%)			
		40 000	60 000	80 000	Mean	40 000	60 000	80 000	Mean	40 000	60 000	80 000	Mean	40 000	60 000	80 000	Mean
		(corn ha^{-1})															
		Corn + soybean															
2002	1:1	161.3	148.7	156.2	155.4	66.8	88.8	96.6	84.0	94.4	59.9	59.6	71.4	58.6	40.3	59.7	46.0
2003		133.5	138.1	144.2	138.6	76.6	76.1	93.2	82.0	56.9	62.0	51.0	56.6	42.6	44.9	35.4	40.8
2002	1:2	147.6	156.1	159.1	154.3	71.8	87.3	93.3	84.1	75.8	68.8	65.8	70.2	51.4	44.1	41.4	45.5
2003		127.5	133.1	134.0	131.5	76.3	76.4	92.0	81.6	51.2	56.7	42.0	49.9	40.2	42.6	31.3	37.9
2002	1:3	138.0	152.3	161.5	150.6	71.7	90.4	95.0	85.7	66.3	61.9	66.5	64.9	48.0	40.6	41.2	43.1
2003		122.5	139.5	149.1	137.0	72.4	80.0	96.3	82.9	50.1	59.5	52.8	54.1	59.1	42.7	35.0	60.5
		Mixture of corn/soybean															
2002	1:1, 1:2, 1:3	149.0	152.4	158.9	153.4	70.1	88.8	95.0	84.6	78.9	63.6	63.9	68.8	53.0	41.7	41.2	44.9
2003		127.8	137.1	142.4	135.8	75.1	77.5	93.8	82.1	52.7	59.6	48.6	53.7	38.8	43.5	65.9	60.6
		Sole corn (plants ha^{-1})															
2002		138.2	141.6	160.0	146.6	–	–	–	–	–	–	–	–	–	–	–	–
2003		125.6	129.3	144.0	133.0	–	–	–	–	–	–	–	–	–	–	–	–
		Sole soybean 200 000 plants ha^{-1}															
2002							72.9										
2003							76.5										

	2002	2003	2002	2003
$S.E_{(0.05)}$ for comparing any:				
2 population means	3.65	3.84	3.30	2.61
2 planting geometry means	NS	NS	NS	NS
2 pop. x planting geometry means	NS	NS	–	–
$t_{(0.5)}$ for comparing intercrop and sole crop means	NS	NS	NS	NS

T a b l e 6. Shoot dry weight (g plant^{-1}) and stem diameter (cm) of corn at 100 DAP as affected by cropping systems of corn and soybean during 2002 and 2003 late cropping season

Year	Cropping geometry (Corn: soybean)	Shoot dry (g plant^{-1})				Stem diameter (cm)			
		40 000	60 000	80 000	Mean	40 000	60 000	80 000	Mean
		(corn plants ha^{-1})							
Corn + soybean									
2002	1:1	9.9	99.0	75.3	91.4	2.9	3.1	1.9	2.6
2003		109.0	110.0	68.3	95.8	3.2	3.0	2.0	2.7
2002	1:2	111.0	95.5	62.1	89.5	2.7	3.0	1.9	2.5
2003		99.0	100.1	65.1	88.1	3.0	3.0	1.8	2.6
2002	1:3	101.3	100.9	69.3	90.5	2.9	3.0	2.0	2.6
2003		93.0	99.2	80.0	90.7	3.0	3.1	2.0	2.7
Mixture of corn/soybean									
2002	1:1, 1:2, 1:3	104.1	98.5	68.9	90.5	2.8	3.0	1.9	2.6
2003		100.4	103.1	71.1	91.5	3.1	3.0	1.9	2.7
Sole corn (plants ha^{-1})									
2002		103.9	96.9	70.3	90.3	3.1	3.0	2.1	2.7
2003		99.2	96.8	70.7	88.9	3.2	3.1	2.2	3.2

	Shoot dry (g plant^{-1})		Stem diameter (cm)	
	2002	2003	2002	2003
$S.E_{(0.05)}$ for comparing any:				
2 population means	8.14	12.41	0.47	0.48
2 planting geometry means	NS	NS	NS	NS
2 pop. x planting geometry means	NS	NS	NS	NS
$t_{(0.5)}$ for comparing intercrop and sole crop means	NS	NS	NS	NS

possible reasons for high incidence of lodging with high population densities, Ransom (2005) suggested that with high plant densities there is less space for roots of individual plants to develop and this would eventually result in the roots usually being less extensive, leading to plants poorly anchored. Nielsen (2006) and Hicks (2004) explained that plant populations that are too high decrease the amount of light in the crop canopy and cause the corn plants to become tall, thin and weak. Klein *et al*., (2004) showed that when plant populations increase, stems become longer and more slender and plant standability decreases. Hence, it was observed that both the corn stem diameters and shoot dry weights were reduced with increase in plant densities of corn. This supports the earlier thesis that increasing plant population decreases the stem girth and plant standability. The increased stalk lodging associated with high plant population was attributed to the reduction in the physical strength of corn-stalks under high plant density. Quite often, weak stalks are the result of the plant cannibalizing and re-mobilizing sugars out of the lower stalk to feed the super-yielding ear (Ransom, 2005; Nielsen, 2006). Poor physical strength of the corn-stalk at this density was therefore attributed to plant-to-plant competition for light, nutrients and water, which enhanced the competition for carbohydrates between the stalk (source) and the ear (sink) within the plant, thus reducing the vigour of the cells in the stalk and predisposing them to lodging (Nielsen, 2006). In addition, Ransom (2005) argued that plants with tall growth habits are more prone to lodging because their centre of gravity is higher than in shorter plant types.

Results of the study also showed that larval counts and damage symptomized by entry/exit holes were greater on widely spaced stands than on closely spaced stands even though lodging was found to occur more extensively on closely than on widely spaced stands. Widely spaced plants received more light and appeared more robust to nourish

Table 7. Grain yields (kg ha^{-1}) of corn and soybean as affected by cropping system of corn and soybean during 2002 and 2003 late cropping seasons

Year	Cropping geometry (Corn: soybean)	Corn				Soybean			
		40 000	60 000	80 000	Mean	40 000	60 000	80 000	Mean
		(corn plants ha^{-1})							
Corn + soybean									
2002	1:1	2112.6	2322.2	1347.3	19.27.4	1333.0	1462.6	1010.0	1268.5
2003		2184.4	2366.6	1597.9	2049.6	1199.0	1525.2	1219.0	1311.4
2002	1:2	2061.3	2300.5	1445.2	1935.7	1525.0	1525.2	1110.0	1386.7
2003		2099.0	2244.1	1507.1	1950.1	1486.0	1531.1	1216.0	1411.0
2002	1:3	2011.8	2206.2	1502.4	1906.8	1403.0	1525.2	1010.0	1312.7
2003		2075.5	2218.8	1499.5	1931.3	1314.0	1409.3	1205.0	1309.4
Mixture of corn/soybean									
2002	1:1, 1:2, 1:3	2061.9	2276.3	1431.6	1923.3	1420.0	1504.3	1043.3	1322.6
2003		2119.6	2276.5	1534.9	1977.0	1333.0	1488.5	1210.3	1343.9
Sole corn (plants ha^{-1})									
2002		2111.2	2321.1	1498.8	1977.0	–	–	–	–
2003		2143.1	2299.7	1520.0	1987.6	–	–	–	–

	Corn 2002	Corn 2003	Soybean 2002	Soybean 2003
$S.E_{(0.05)}$ for comparing any:				
2 population means	–	–	1815.7	1904.0
2 planting geometry means	108.9	146.4	93.3	58.6
2 pop. x planting geometry means	NS	NS	NS	NS
$t_{(0.5)}$ for comparing intercrop and sole crop means	NS	NS	NS	NS

more larval populations than weaker and slender stands of densely populated plants. On the other hand, the number of entry/exit holes per unit cross sectional area may be higher on the densely populated stands with slender girths than on the sparsely populated stands with bigger or wider stem girth. Here, in this study, the stalk girths of sparsely populated stands were bigger than the stalk girths of the densely populated stands and therefore the bigger stalks were better able to withstand lodging than stands with thinner girths. This may be why Van Dyk (2001) concluded in USA that European corn borers may not be the major factor in the lodging of corn in most fields worked. Therefore the increased plant damage per unit cross sectional area, the relatively thinner stands and the increased corn-stalk elongation obtained at high population densities in this study probably accounted for the poorest grain yield obtained and the increased stem lodging recorded at this population. This is in agreement with the report by Nielsen (2006) who confirmed that plant population levels that are too high will decrease the amount of light in the crop canopy and cause the corn plants to produce smaller than normal yield. The results of this investigation also showed that neither planting geometry, crop mixtures nor the interaction of crop geometry and density influenced the extent of stem lodging of the plants, stem borer damage, plant height, shoot dry weight or the grain yield of the corn component, However, Mahadevan and Chelliah (1986) reported that growing sorghum in association with cowpea or lablab reduced sorghum stem borer infestation. They attributed this reduction to earlier coverage by lablab and cowpea leaves in the early crop stages and to lesser oviposition by *Chilo partellus* moths. Amoako-Atta *et al*., (1983) earlier suggested that cowpea and sorghum at similar height in their early stages would reduce visual stimuli that attract the borer moth to sorghum for oviposition. Tahvanainen and Root (1972) suggested that the biological complexity would affect the olfactory stimuli and alter the insect behaviour in the crop. Finally, Mahadevan and Chelliah (1986) rested their argument by concluding that the phytochemicals produced by lablab or cowpea would have altered the oviposition behaviour of gravid moths of *C. partellus* and led to less damage to sorghum by the stem borer in the intercropped system. In this study, these relationships were not evident. Neither the stem borer larval population nor stalk damage symptomized by entry/exit hole counts in corn were affected by intercropping corn with soybean. This could be attributed to the relative higher advantage of corn over soybean in the mixture. The relative height differences between corn and soybean throughout the experimental period were enormous and could mask any physical barrier expected to be caused by the legume canopy. Geometric alterations involving row-to-row modifications of corn and soybean were also not sufficient to produce enough excessive vegetative variation needed to fully create the physical perturbation that could affect the pest population. This was attributed to the uniform intervening spaces between corn plants in mixture, which eventually existed following the height advantage of corn over soybean. These uniform intervening spaces existed irrespective of the planting geometry, especially under comparable population pressure. Furthermore, the height differential between soybean and corn varieties used in this study perhaps reduced the chances of the phytochemicals (if any) produced by the legume component from reaching the foliage of corn to alter the oviposition behaviour of the stem borer as suggested by Mahadavan and Chelliah (1986).

At corn seedling stage (50 DAP), the data on incidence of borer larvae followed a similar trend as was reported earlier. This is probably because the soybean plants were not yet of full vegetative development at this stage. Consequently, there was reduced soybean canopy interference with the distribution of the species. This could support earlier reason why neither the intercrop nor geometric configuration of the association could affect infestation of the pest at this stage.

Root lodging, on the other hand, was also not affected by population densities, planting geometry or their interaction, as root lodging in corn was primarily caused by termites (Youdeowei, 2004) which are subterranean and their infestation is dependent on weather.

CONCLUSIONS

1. Spacing is of paramount importance in the lodging and infestation of corn-stalk by the borers. The wider the corn spacing, even in mixtures with soybean, the bigger the corn-stalk diameter and the higher the ability to withstand infestation and lodging by the stalk borers.

2. Dense plant populations were more prone to stalk lodging irrespective of their reduced infestation and damage by the borer larvae.

3. The taller plant heights, smaller shoot dry weights and stem diameter of plants in dense populations make them more susceptible to lodging than the shorter plant heights, bigger shoot dry weights and stem diameters of plants in sparse populations.

4. Generally, geometric arrangements of corn and soybean on the ground did not influence lodging of corn-stalks. Farmers in this region should therefore ensure adequate corn spacing that would produce robust plants, able to withstand borer menace and, at the same time, ensuring optimum grain production.

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