Effect of Plant Populations on the Incidence of Bean Stem Maggot (*Ophiomyia* spp.) in Common Bean Intercropped with Maize

Kalista H. PETER[1], George B. SWELLA[2] and Deus M. K. MUSHOBOZY[3]

[1]Dodoma University, Dodoma, Tanzania; [2]Tanzania Official Seed Certification Institute, Morogoro, Tanzania; [3]Department of Crop Science and Production, Faculty of Agriculture, Sokoine University of Agriculture, Chuo Kikuu, Morogoro, Tanzania

Abstract

Peter K.H., Swella G.B., Mushobozy D.M.K. (2009): **Effect of plant populations on the incidence of bean stem maggot (*Ophiomyia* spp.) in common bean intercropped with maize**. Plant Protect. Sci., **45**: 148–155.

Effects of three intercrop combinations and plant populations on bean stem maggot *Ophiomyia phaseoli*; *O. spencerella* and *O. centrosematis* was observed; with the latter being reported in Morogoro for the first time. The infestation was higher in the pure stands of beans than in the intercrops and decreased gradually down to two-thirds maize. The incidence of *Ophiomyia* spp. decreased with increasing plant populations. Low counts of larvae and pupae were recorded in intercrops. Stem damage was higher in pure bean plots, which also had higher larvae and pupae counts. The intercrop combinations gave a yield advantage at all plant populations except at population P_3 for one – third maize two thirds bean mixture. The highest yield advantage was obtained at P_2 for two thirds maize – one third beans treatment suggesting it to be the optimum combination for the two crops. It is concluded that a combination of BMM (one third bean-two thirds maize) at plant population P_2 may be considered as one of the *Ophiomyia* spp. management strategy in common bean.

Keywords: *Ophiomyia*; pests; species; damage; yield advantage

Bean stem maggot (*Ophiomyia* spp.) is one of the insect pests that most seriously affect production of common bean (*Phaseolus vulgaris*) in tropical and sub-tropical countries of the world. Three species of Ophiomyia are known to be associated with beans. They include *O. phaseoli* (Tryon); *O. spencerella* (Greathead) and *O. centrosematis* (Greathead), their distribution varies with location (Abate & Ampofo 1996). Losses up to 40% have been reported. Intercropping is the main cropping system in the tropics, the system is practiced primarily to ensure food security for farmers (Orawu *et al.* 2001).

However, intercropping of cereals and grain legumes is a neglected theme in agricultural science and practice in both conventional and organic (Dahlmann & Von Fragstein 2006). According to Tsubo *et al.* (2005) cereal-legume intercropping plays an important role in subsistence food production in both developed and developing countries, especially in situations of limited water resources. Intercropping of grain legumes and cereals regulate soil temperature and increase water holding capacity, adds to the soil organic matter and increase protein contents of cereals.

Crop production is generally difficult in the tropics because the favourable conditions promote pest development (Orawu *et al*. 2001). However, in some cases pest incidences appear to be less in intercropping systems (Kyamanywa & Ampofo

1988). According to Gabriele (2003) considerable evidence has emerged over the past twenty years to suggest that pest populations and problems are much greater in crop grown in monoculture than those grown with intercropping. Growing two or more crops in the same field at the same time enhances natural enemy abundance and generally keeps pest number at low levels (Abate *et al.* 2000). In an intercropping system one component crop may act as a physical barrier reducing the lateral spread of pests for example *Aphis* spp.

In Tanzania, little is known on the influence of intercropping on bean stem maggot development in common bean intercropped with maize. Therefore, it was the objective of this study to investigate the effect of bean – maize intercropping on population patterns of bean stem maggots on bean.

MATERIALS AND METHODS

The study was conducted in the field at Sokoine University of Agriculture, Morogoro, Tanzania during the 2001 and 2002 main cropping seasons. A susceptible determinate bean cultivar TMO 241 and a maize cultivar TMV-I were used in this study. Fertiliser triple superphosate (TSP) at rate of 50 kg P/ha was drilled in the rows at the time of planting, 60 kg N/ha in the form of ammonium sulphate was top dressed when maize reached a 6–10 leaves stage and beans at 14 Days after Emergence (DAE). The plots were kept weed free throughout the growing season by hand weeding. The bean plants did not receive any pesticide sprays.

Experimental design and treatments. The experimental design was a split plot design with three replicates. The intercropping combinations and pure stand of bean were the main treatments, while the plant populations were the sub treatments. The main treatments were 6 m wide and 15 m long.

The mixtures were achieved following a displacements series technique (de Wit 1960) by sowing complete rows in the required proportions (Mohamed & Karel 1986). In this study, a plant equivalent ratio of three common bean plants to one maize plant has been used (Karel & Matary 1983). The two thirds maize and one third beans treatment, one third maize two thirds beans, pure stand beans and maize were designated as BMM, BBM, BBB and MMM respectively.

The intercrop combinations were obtained by planting complete rows of common bean or complete rows of maize in required proportions. Thus, two thirds BBM was achieved in a block of six rows by replacing two rows of pure bean treatment with a row of maize. Similarly, BMM was achieved by replacing four of every six rows of pure bean treatment with two rows of maize (Figures 1 and 2).

Three plant population levels were used as half optimum, the optimum and twice the optimum designated as P_1, P_2, and P_3, respectively. The three plant populations were obtained by altering the within row spacing between the plants, and having a constant row width, which for maize was 75 cm and for beans 37.5 cm. Within the rows, spacing for beans was 40 cm, 20 cm and 10 cm which

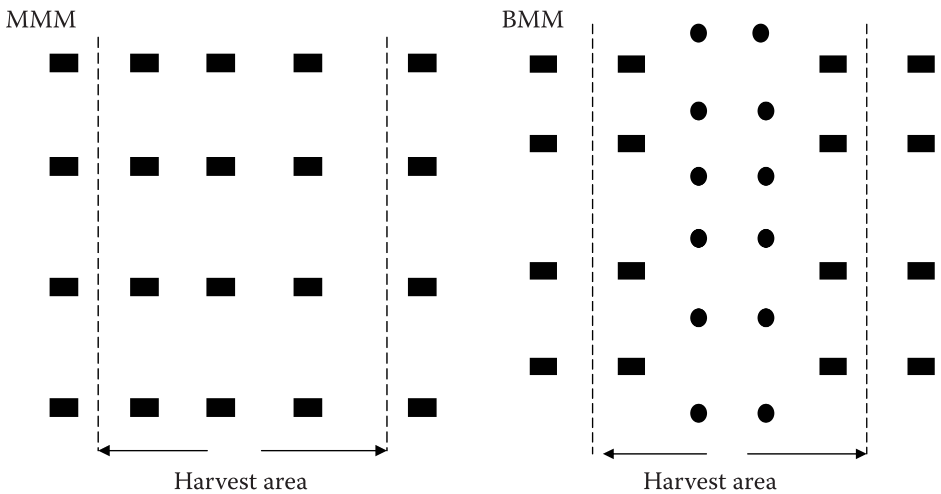

Figure 1. Arrangement of crop rows for the replacement series treatments showing number of rows for each species in a harvest area (MMM: 3 rows of maize; BMM: 2 rows of maize and two rows of bean)

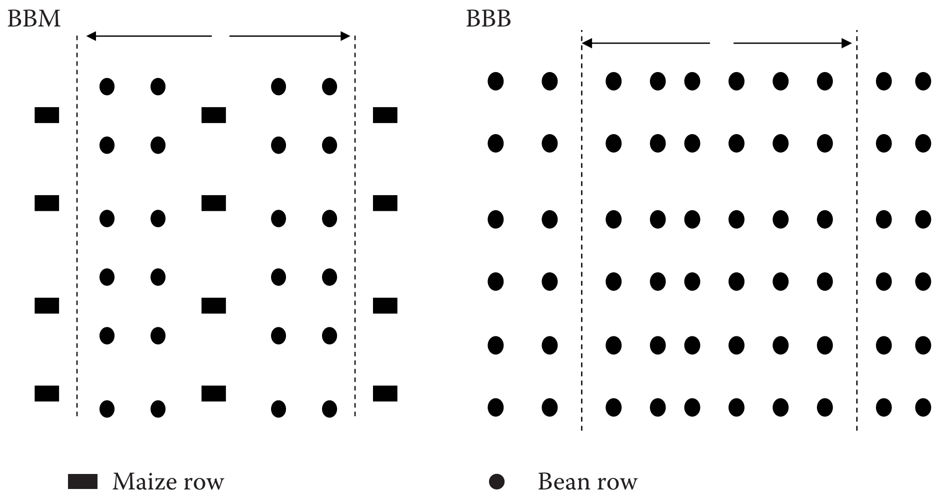

Figure 2. Arrangement of crop rows for the replacement series treatments showing number of rows for each species in a harvest area (BBM: 1 row of maize and 4 rows of beans; BBB: 6 rows of bean)

gave a plant population of 66 666, 133 333, and 266 666 plants per hectare which were designated as P_1, P_2 and P_3, respectively. For maize spacing used were 60 cm, 30 cm and 15 cm which gave 22 222; 44 444, and 88 888 plants per hectare and were designated as P_1, P_2, and P_3, respectively.

Seed yields for common bean and maize were determined by harvesting a constant total harvest area of 11.25 m^2 (5 × 2.25 m). The number of rows harvested for each crop in the treatments depended upon the proportion of each crop in the treatments. The number of rows harvested for component crop is shown in Figures 1 and 2.

The optimal intercrop ratios were calculated by using the "relative yield total" technique suggested by De Wit and Van den Bergh (1965).

Data collected. Data collected included ovipuncture counts at 14, 21, 28, and 35 DAE. Oviposition punctures counts were scored by counting ovipunctures on 5 randomly selected plants in each plot. This was achieved by holding the sampled plant leaf at a slanting position against sunlight.

Table1. Mean number of ovipunctures per 5 plants made by bean stem maggots on common bean leaves

Treatment	14 DAE		21 DAE		28 DAE		35 DAE	
	2001	2002	2001	2002	2001	2002	2001	2002
Main treatment								
BBB	20.3	23.0	27.0	30.8	21.0	23.4	9.1	12.2
BBM	17.0	19.6	21.4	25.7	17.4	19.5	8.8	11.3
BMM	13.1	15.8	22.2	26.1	17.4	18.6	7.3	10.0
Mean	16.8	19.4	23.5	27.5	18.5	20.5	8.4	11.1
Sub treatment								
P_1	17.0	19.5	20.1	23.3	15.9	17.6	8.3	10.5
P_3	14.6	17.2	24.7	27.4	17.7	19.5	8.7	11.9
P_2	18.9	21.4	25.9	29.1	22.1	24.0	8.2	10.6
Mean	16.8	19.3	23.5	26.6	18.5	20.4	8.4	14.5
MTxST	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	27.21	17.60	44.46	26.25	30.26	20.20	22.50	28.75

DAE – days after emergence; BBB – pure-stand bean; BBM – two-third bean, one third maize; BMM – one third bean, two thirds beans two thirds maize; NS – not significant at $P < 0.05$

Table 2. Mean number of larvae and pupae of *Ophiomyia* spp per plant in pure stand and intercropped beans and maize at different plant population densities

Treatment	14 DAE						21 DAE						28 DAE					
	O_s		O_p		O_c		O_s		O_p		O_c		Os		Op		O_c	
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
Main treatment																		
BBB	4.1^{a}	5.5^{a}	2.7^{a}	4.3^{a}	1.8^{a}	3.2^{a}	3.6^{a}	4.0^{a}	1.5^{a}	2.9^{a}	1.2^{a}	2.6^{a}	2.8^{a}	3.1^{a}	1.8^{a}	2.7^{a}	1.0^{a}	1.2^{a}
BBM	2.2^{ab}	3.8^{b}	0.7^{c}	2.2^{c}	0.8^{b}	2.1^{a}	2.4^{a}	3.4^{b}	1.2^{a}	2.2^{ab}	0.9^{a}	2.2^{ab}	1.6^{b}	2.9^{a}	1.7^{a}	2.2^{ab}	0.9^{b}	1.4^{a}
BMM	1.6^{b}	3.1^{b}	0.9^{b}	2.5^{c}	0.9^{b}	1.2^{a}	1.6^{a}	3.0^{b}	1.1^{a}	1.5^{b}	0.9^{a}	1.7^{c}	1.7^{b}	1.8^{b}	1.0^{b}	1.3^{b}	0.8^{b}	1.1^{a}
Mean	2.6	4.1	1.4	3.0	1.2	3.1	2.5	3.5	1.3	2.2	1.0	2.2	2.0	2.6	1.5	2.0	0.9	1.2
Sub treatment																		
P_1	3.2^{a}	4.7^{a}	2.1^{ab}	3.5^{a}	0.9^{a}	2.3^{a}	2.9^{a}	4.1^{a}	1.5^{a}	2.9^{a}	1.0^{a}	2.3^{b}	2.1^{ab}	2.7^{a}	1.7^{a}	2.4^{a}	0.9^{a}	1.2^{a}
P_2	2.6^{ab}	4.1^{a}	1.1^{a}	2.6^{c}	1.1^{a}	2.7^{a}	2.1^{ab}	3.6^{b}	1.5^{a}	2.1^{ab}	0.8^{a}	2.1^{ab}	1.7^{a}	2.6^{a}	1.1^{a}	2.1^{ab}	1.2^{a}	1.4^{a}
P_3	1.8^{b}	3.5^{b}	1.8^{a}	3.2^{ab}	1.0^{a}	1.1^{a}	1.9^{b}	2.8^{c}	0.7^{a}	1.6^{b}	0.9^{a}	2.2^{ab}	1.9^{a}	2.6^{a}	1.0^{a}	1.5^{b}	0.8^{a}	0.4^{b}
Mean	2.5	4.1	1.7	3.0	1.0	3.0	2.3	3.5	1.2	2.2	0.9	2.2	1.9	2.6	1.3	2.0	0.8	1.1
(MT × ST)	NS	*	NS	*	NS	*	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	10.45	21.6	15.54	N0	17.26	25.70	8.01	10.25	14.92	9.67	16.20	8.60	12.90	26.40	18.44	14.80	13.46	

In a column, means followed by same letter(s) are not significantly different at 5% level (Duncan's Multiple Range Test)

O_s – *Ophiomyia spencerella,* O_p – *O. phaseoli,* O_c – *O. centrosematis*
MT – main treatment, ST = sub treatment; NS – not significance at $P < 0.05$; *significant at $P < 0.05$

Table 3. Mean stem damage scores on common bean and seed yield per plant

Treatment	21 DAE		28 DAE		35 DAE		Seed yield (g) per plant	
	2001	2002	2001	2002	2001	2002	2001	2002
Main treatment								
BBB	3.6[a]	4.1[a]	3.8[a]	4.2[a]	4.0[a]	4.0[a]	9.8[b]	7.6[b]
BBM	3.0[ab]	3.8[a]	3.6[a]	3.8[a]	3.2[b]	3.6[b]	20.1[a]	18.6[a]
BMM	2.4[b]	3.2[b]	2.8[b]	3.4[b]	3.0[b]	3.2[b]	12.8[b]	11.4[b]
Mean	3.0	3.7	3.3	3.8	3.4	3.6	14.2	12.5
Sub treatment								
P_1	3.4[a]	2.8[a]	3.0[a]	3.4[b]	3.8[a]	3.6[b]	16.5[a]	13.5[b]
P_2	2.5[b]	3.6[b]	2.4[b]	3.0[b]	3.0[b]	3.2[b]	10.8[b]	8.7[b]
P_3	2.6[b]	3.0[b]	2.8[ab]	3.0[b]	3.4[a]	3.0[b]	11.2[b]	9.6[b]
Mean	2.8	3.4	2.7	3	3.4	3.2	14.2	10.3
CV (%)	17.4	15.63	13.30	11.25	27.4	21.64	18.70	26.40

In a column, means followed by same letter(s) are not significantly different at 5% level (Duncan's Multiple Range Test)

Oviposition punctures which contain eggs appear shiny whereas feeding punctures are dull (Irving 1986).

Larvae and pupae counts were scored by counting all larvae and pupae after dissecting the main stem and branches of 5 randomly selected plants per plot at weekly intervals from 14 to 35 DAE. The data are reported as an average of three counts. Different species of *Ophiomyia* were identified following Irving's (1986) method.

Plant damage was assessed by using a visual scale of 1–5 where 1 = no damage, 2 = slight damage, 3 = moderate damage, 4 = severe damage, 5 = complete damage and plant dying (Karel & Maerere 1985).

Data analysis. The data were subjected to two-way analysis of variance of MSTAT-C statistical package and the means were separated at $P < 0.05$ by Duncan's (1955) multiple range test.

RESULTS

Table 1 shows the mean number of ovipuncture counts of common beans for the two seasons. There was no significant ($P < 0.05$) difference among the various treatments. Although more ovipuncture were observed in the 2002 cropping seasons, there was generally more ovipunctures in pure bean stands (BBB). A gradual decrease of ovipunctures was observed as the proportion of maize increased in intercrop combinations from BBM to BMM. The ovipuncture counts increased from 14 to 21 DAE in pure stands bean and bean-maize intercrops and decreased gradually afterwards in both seasons.

The ovipuncture counts were not significantly ($P < 0.05$) different among the different population densities. Ovipuncture counts were highest at 21 DAE after which they started to decrease gradually in the two seasons. However, relatively higher counts were observed at P_1 and they decreased as plant population was increased.

Overall, the infestations by the bean stem maggots were low during the first cropping season. The three species of the bean stem maggots, *0phiomyia phaseoli, O. spencerella* and *O. entrosematis* were found to be present in all treatments with *O. centrosematis* being reported in Morogoro for the first time and the most dominant species was *O. spencerella* followed by *O. phaseoli* (Table 2). For all species, the larvae and pupae counts were higher in pure stands than in mixtures. In pure bean plots (BBB) the larvae and pupae counts for all species were highest at 14 DAE and decreased gradually afterwards to 35 DAE except for *O. phaseoli* at 28 DAE. Other treatments followed a similar trend. There was no significant difference ($P < 0.05$) in larvae and pupae counts for all species at the three plant population densities studied.

Table 4. Relative Yield Total (RYT) of common bean and maize intercropped with different plant populations

Treatment	BMM		BBM		Mean	
	2001	2002	2001	2002	2001	2002
P_1	1.16	1.10	1.23	1.04	1.19	1.O7
P_2	1.25	1.21	1.14	1.15	1.20	1.18
P_3	1.17	0.99	0.73	1.01	0.95	1.00

However, higher counts were predominantly recorded at the lowest plant population P_1 than at the highest plant population P_3. This trend was particularly evident with *O. spencerella* at 14 DAE and 21 DAE where larvae and pupae counts at P_1 and P_3 were significantly ($P < 0.05$) different for the consecutive seasons.

Stem damage was higher in pure bean plots which also had the highest larvae and pupae counts followed by BBM and lastly BMM (Table 3). Stem damage increased from 21 DAE to 28 DAE after which it remained constant and it was generally rated as slight to moderate.

There was a significant ($P < 0.05$) difference in the seed yield per plant among the main treatments. Treatment BBB which had higher ovipuncture, larvae and pupae counts and higher stem damage score recorded the lowest seed yield. The highest yield was recorded in BBM plots. Treatments P_1 and P_2 which had higher ovipuncture, larvae and pupae counts had generally higher stem damage and significantly the lowest seed yield per plant.

The mixtures gave yield advantage at all plant populations except at P_3 for one – third maize two-thirds bean mixtures (Table 4). The biggest yield advantage was obtained at BMM intercrop combination with plant population P_2.

DISCUSSION

The ovipuncture counts increased from 14 DAE to 21 DAE in all bean and maize intercrops and decreased gradually afterwards. The decreasing ovipuncture counts as the bean plants matured indicate that the flies are not able to puncture older leaves for oviposition effectively. Yields were slightly lower in the 2002 cropping season partly because of high stem maggot infestation.

The relatively higher counts of ovipunctures observed at P_1 and the gradual decrease as the plant population increased is in accordance with the findings by Mohamed and Karel (1986) who reported a significant and gradual decrease in ovipuncture counts with increasing plant populations. This may be attributed to the high density of plant vegetative matter interfering or restricting the landing process of beanflies for oviposition on bean leaves.

Observation of *O. centrosematis* for the first time in Morogoro suggests that all three species of *Ophiomyia* are present in the area. *O. phaseoli* was first reported by (Karel 1981 in Karel & Maerere 1985) and *O. spencerella* was later reported by Oree *et al.* (1988). The differences in observation of these species at different times may be attributed to the differences in the cropping patterns, seasonal population dynamics as well as time of sowing or a misidentification of the pest species in part. Various studies on the effect of bean plant population levels on the incidence of the bean stem maggot has been giving different results. A significant decrease in larvae and pupae counts was recorded with increasing plant population suggesting that higher plant population diluted the activities of bean stem maggot (Karel & Mghogho 1985). Mohamed and Karel (1985) did not observe a significant effect of plant population on the larvae and pupae counts of *Ophiomyia phaseoli*. The different results observed may be attributed to the growth habits of different cultivars used in various studies affecting the crop architecture, the cropping pattern and seasonal variation in weather conditions.

The low number of larvae and pupae recorded in intercrops in this study in both cropping seasons supports previous report by Mohamed and Karel (1985) who attributed it to the barrier effect produced by maize which restricts the bean stem maggot movement activities and also a modification of the general crop architecture and consequent failure of recognition of the host crop which may have had an effect on the colonization process. An increase in the natural enemy populations of bean stem maggots could have also contributed to the observed population trend in intercrops. Karel (1993) observed a similar trend on pod borer population in a bean-maize intercrop. Kyamanywa and Ampofo (1988) reported the low numbers of thrips in the cowpea intercrop with sorghum which was attributed to reduced incident light which is important for this pest's activities at the cowpea canopy because the sorghum grows taller thus intercepting most of the light intensity. Nevertheless, the diverse fauna and flora may have stabilizing effects on the pest and disease pressure. It also implies that other strategies need to be employed to augment mixed cropping as a disease /pest management strategy (Orawu *et al.* 2001).

Higher mean stem damage scores which were recorded in BBB crop combinations which also had recorded the highest larvae and pupae counts for all *Ophiomyia* spp. recorded signifies a relationship between the number of the larvae and pupae and the amount of damage caused. Bean stem maggots are known to feed on the cortical tissues of the stem on their way down to the stem base for pupation (Abate *et al.* 2000). The more the number of larvae and/or pupae per plant the more is the stem damage.

The lowest seed yield per plant recorded in BBB treatment shows the effect of the bean stem maggots on the stem base which disrupts the nutrient translocation system in bean plants. The low yields in the BMM treatment which had low counts of larvae and pupae could be attributed to increased intra and interspecific competition in the crop associations rather than bean stem maggot infestation.

The highest yield advantage was obtained at P_2 for BMM treatment, suggesting it to be the optimum proportion combination for the two species. Yield advantages may have occurred due to morphological differences between maize and beans. Differential utilisation of environmental resources and lower populations of important pests in the mixtures (Karel 1993), and moreover, a difference in maturity period for the two crops may have contributed to the yield advantages in the intercrops. Beans matured on an average number of 71 days while maize matured after 120 days. The difference in exerting maximum pressure on the available resources at different times could have resulted into a yield advantage (Orawu *et al.* 2001). According to Bolarinwa (2008) incidence of Soft Rot Disease (SRD) on cocoyam was lower, less than 50% in cassava intercropped with cocoyam compared to 68% SRD in pure cocoyam. Revenue realised from cassava was higher N115, 125:00 than N 37, 500:00 realised from cocoyam sole.

The results from the present study have shown that an intercrop of bean at one third bean and two thirds maize (BMM) at a plant population P_2 which had the best relative yield advantage could make one strategy in the management of bean stem maggots in farmers' fields. This will be advantageous to farmers who are facing land shortage and their bean crop being threatened by bean stem maggot infestation at the same time being required to grow these two staple crops.

Acknowledgements. We gratefully acknowledge staff of the SUA farm for their support and cooperation. We are further indebted to Dr. Doug George of the University of Queensland for his encouragement and advice when preparing this manuscript.

References

Abate T., Ampofo J.K.O. (1996): Insect pest of beans in Africa. Their ecology and management. Annual Review of Entomology, **41**: 45–73.

Abate T., Van Huis A., Ampofo J.K.O. (2000): Pest management strategies in tropical agriculture. An African perspective. Annual Review of Entomology, **45**: 631–659.

Bolarinwa K.K. (2008): Control of incidence of Soft Rot Cocoyam Disease using intercrop of cocoyam with cassava; Farmers' sustainable livelihood strategy in Oyo state, Nigeria. Journal of Applied Sciences Research, **4**: 1352–1355.

Dahlmann C., Von Fragstein N.P. (2006): Influence of different seed rates, sowing techniquea and N supply on grain yield and quality parameters in intercropping system. Available at htt://orgprints.org/secure/00003164/01/Dahlmann Odense paper.doc

De Wit C.T. (1960): On competitionae verslagen landboukunding ondorzeck. Agriculture Research Reports, 66 (8). Pudoc, Wageningen.

De Wit C.T., Van Den Bergh J.B. (1965): Competition between cabbage plants. Netherlands Journal of Agricultural Science, **13**: 212–221.

Duncan D.B. (1955): Multiple range and multiple *F* tests. Biometrics, **11**: 1–42.

Gabriele S. (2003):Natural crop protection in the tropic. Available at htt//www.naturalcropprotection.margraf-verlage.de/intercrop.htm

Irving N.S. (1986): Species identification. In: Allen D.J., Smithson J.B. (eds): Proceedings of the Beanfly Workshop, 16–20 November 1986. Arusha, Tanzania Pan African Workshop Series No 1. CIAT, Cali Colombia.

Karel A.K. (1993): Effect of intercropping with maize in the incidence and damage caused by pod borers of common beans. Environmental Entomology, **22**: 1076–1088.

Karel A.K, Matary R.D. (1983): The effect of insecticide application and plant populations on insect pests and yield of intercropped maize and beans. Bean Improv. Coop., **26**: 43–45.

Karel A.K., Maerere A.P. (1985): Evaluation of common bean cultivars for resistance to beanfly (*Ophiomyia phaseoli* Tryon). Annual Report of the Bean Improvement Cooperative, **28**: 15–17.

Karel A.K., Mghogho R.M.M. (1985): Effects of insecticides and plant population on the insect pests and yield of common bean (*Phaseolus vulgaris* L). Journal of Economic Entomology, **78**: 917–921.

Kyamanywa S., Ampofo J.K.O. (1988): The effect of cowpea/maize mixed cropping on incident light at the cowpea canopy and flower thrips (Thysanoptera: Thripidae) population density. Crop Protection, **7**: 186–189.

Mohamed A.H., Karel A.K. (1985): Effects of plant population density on insect and seed yield of common beans intercropped with maize. In: Minjas A.N., Salema M.P. (eds): Proceeding 4th Workshop on Bean Research in Tanzania held at Sokoine University of Agriculture. Morogoro, Tanzania September 5–7, 1985: 69–77.

Orawu M., Adipala E., Warren H. (2001): Influence of cowpea/sorghum intercropping on occurrences of disease and insect pests in Eastern Uganda. In. African Crop Science Conference Proceedings, Vol. 5**:** 409–412.

Oree A., Mphuru A.N., Yarro J.G. (1988): Study on species composition and temporal populations changes of the beanfly (*Ophiomyia* spp) and its implications on screening for resistance in beans. In: Salem M.P., Minjas (eds): Proceedings of the 7th Bean Research Workshop, Sokoine University of Agriculture, Morogoro, Tanzania, September 28–30, 1988.

Tsubo M., Walker S., Ogindo H.O. (2005): A simulation model of cereals-legume intercropping systems for semi-arid regions. Department of Soil, Crop and Climate Sciences, University of the Free State. Field Crops Research, Vol. 93, No. 1.

Received for publication May 18, 2009
Accepted after corrections September 16, 2009

Corresponding author:

Kalista Higin Peter, MSc, Dodoma University, P.O.Box 259, Dodoma, Tanzania
tel.: + 255 262 323 003 or + 255 754 281 132, fax: + 255 262 323 001, e-mail: kalistashao@yahoo.com