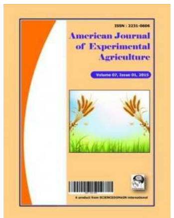

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Evaluation of Common Bean (*Phaseolus vulgaris* L.) Varieties for Resistance to Bean Stem Maggot (*Ophiomyia* spp.) in Kenya

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Authors' contributions

This work was carried out in collaboration between all authors. Author GJK designed the study and wrote the protocol. Author GJK collected the data and performed the laboratorial analyzes. Authors GJK and JJK analyzed the data and wrote the first draft of the manuscript. Author GJK managed the field study throughout the experiment period. Authors MK, OK, FMEW, JJC, SKK and JKN reviewed the draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Common bean is the most important pulse crop in Kenya, though small scale farmers involved in its farming have limited access to quality seeds resistant to pests such as bean stem maggot, thereby limiting its production from potential yield production of 2000 kg ha^{-1} to less than 1000 kg ha^{-1}. This study was therefore aimed at determining effective ways of managing bean stem maggot through identification and selection of resistant commercial varieties for enhanced host resistance. This was achieved through screening levels of resistance among commercial varieties and determining severity and incidence of bean stem maggot infestations. The study was conducted in Kakamega, Njoro and Uasin-gishu. The varieties were planted together with two local checks; KK 8, Tasha, KK

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15 (Resistant check), Chelalang, Wairimu dwarf, Ciankui, GLP 585, Miezi mbili, GLP 2 (Susceptible check), GLP 1004, GLP 24, and GLP 1127. A score of 1-9 scale (1-3 highly resistant, 3-5 resistant, 5-7 susceptible and 7-9 highly susceptible) was used. The experimental design used was RCB (Randomized Complete Block) design with three replications. Data collected was subjected to ANOVA using SAS program version 9.1, considering varieties as fixed and replicates as random factors. The results showed that the bean varieties resistant to bean stem maggot were; Chelalang, Tasha, GLP 1004, KK 8, GLP 585 and KK 15. The resistant varieties deter bean stem maggot attack and are recommended for use by farmers in the country.

Keywords: Ophiomyia spp; Phaseolus vulgaris; resistant; susceptible.

1. INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is the most common grain legumes consumed worldwide and is the most important grain legumes and source of proteins for most Kenyan households [1]. It is the world's most important food legume and ranks second after the cereal maize as a staple food crop grown by more than a thousand households in Kenya [2]. It is a popular crop among small scale farmers mainly for subsistence, nitrogen fixation and marketing of the surplus [3,4]. Additionally, its short growth cycle and moderate rainfall requirements permit production even in seasons when rainfall is erratic [3].

The production of common bean is hampered with many challenges including pest and parasites, with bean stem maggot (*Ophiomyia spp*) being common and serious pest in tropical countries [5,6]. On the other hand, the most common bean seed varieties, developed by international and national research agencies in the 1990s, have been passed from farmer to farmer and saved from season to season, reducing the purity of the stock and increasing susceptibility to the pest [5]. Generally, the major biotic constraints to bean production in Kenya and other Sub-Saharan countries include insect pests such as bean stem maggot among others, which cause significant yield losses of 30-100% [7]. The bean stem maggot occurs more frequently in association with the root rot diseases than alone and is a major cause of low bean yields, especially in dry seasons [8,5].

Use of resistant cultivars is a major pest management practice and crops grown in fertile soils also exhibit resistance to pests [9]. Therefore, development of resistant cultivars is promising as a means of control, but sustained research is needed. Reports on resistance have been put out by, among others, [10,11]. Despite the current effort, much research is still needed for elaborate conclusions to be drawn. This study focused on devising the effective management of bean stem maggot through identification and selection of resistant commercial varieties of common beans, for enhanced host resistance and hence increased yield.

2. MATERIALS AND METHODS

The study was conducted in Njoro, Uasin-Gishu and Kakamega Counties during the short rainy seasons between the months of August to December in the year 2014, for one season each. The KALRO Thika program developed varieties for the medium and high potential areas. Thika varieties used included GLP 2, GLP 24, GLP 1004, GLP 92 and GLP 585. Egerton University varieties were; Chelalang, Tasha and Ciankui and other varieties were sourced from KALRO Kakamega which included; KK 8, KK 15, Wairimu dwarf and Miezi mbili, all of which were evaluated for bean stem maggot. Two varieties, KK 15 and GLP 2 were used as resistant and susceptible control respectively. The scale of 1-9 [12] score was used to screen the varieties in the field and in the screen house.

2.1 Screen House Experiment

Each of the twelve varieties were planted in polythene bags and replicated three times in a RCBD design. At seven days post planting, they were infested with bean stem maggot (*Ophiomyia* spp.) at pupal stages. The bean stem maggot pupae were collected from infested bean plant stems from the fields. The bean plants were dissected at the base where the pupae lodge and the pupae were removed and kept in a clean cotton cloth. Ten pupae were placed in the polythene bags containing the plants in the screen house. These pupae developed into flies which started their life cycle again by laying eggs on the bean leaves, eggs hatched into larvae which tunneled through the stem to the base where they pupate. Bean stem maggot screening was done using the scale of 1-9 score [12] after 7, 14, 21 and 28 days after infestation using a scale of 1-9 score [12].

2.2 Statistical Analysis

Data collected was subjected to ANOVA (Analysis Of Variance) considering varieties as fixed and replicates as random factors. The mean comparison test used to separate significantly different treatments is Fischer's least significant difference (LSD).

2.3 Severity and Incidence of Bean Stem Maggot Infestation

The varieties were laid in a RCB design and replicated three times. Spacing was done at 30 cm x 15 cm inter and intra-row spacing respectively, ten plants from the two middle rows of each plot tagged randomly for evaluation. The numbers of dead plants were recorded from two weeks after emergence up to the fifth week for the plots subjected to natural bean stem maggot infestation. During the same period, the pupae and larvae in the stems of all selected and sampled plants from each plot were removed and counted. Days to 50% flowering, days to physiological maturity, 100-seed weight and seed yield which were recorded on naturally infested plots.

3. RESULTS AND DISCUSSION

3.1 Level of Resistance among Commercial Varieties of Common Bean

Using the scale 1-9 [12], the varieties that showed positive results on resistance were; KK 8, Tasha, KK 15 (resistant control), Chelalang, GLP 585, and GLP 1004 while the susceptible ones were Wairimu dwarf, Ciankui, Miezi mbili, GLP 2 (susceptible control), GLP 24 and GLP 1127 as illustrated in Table 1. Resistant varieties had larvae means of between 6.33 and 8.33 and the pupae means between 7.33 and 9.33 while the susceptible varieties had means of larvae count between 16.67 and 20.00 and pupae count of between 17.33 and 20.00. After the screen house experiment, the varieties which were confirmed to be resistant to bean stem maggot attack were; Chelalang, Tasha, GLP 1004, KK 8, GLP 585 and KK 15 (Resistant check) and the tolerant one was GLP 1127 while the susceptible varieties were; Wairimu dwarf, Ciankui, Miezi mbili, GLP 24 and GLP 2 (Susceptible control).

The score of 1-9 scale [12] used in the study showed that six out of the twelve varieties tested, were resistant and could be used by farmers to improve production. Increased common bean yield in the fields would therefore

Table 1. Means of bean stem maggot larvae and pupae in screen house experiment per plot average

Varieties	Larvae	Pupae	(1-9 scale) Score
KK 8	6.67^{de}	19.33^{cd}	1-3 (highly resistant)
Tasha	7.33^{cd}	7.67^{e}	3-5 (resistant)
KK 15 – Resistant check	7.67^{cd}	9.33^{cd}	3-5 (resistant)
Chelalang	6.33^{e}	8.67^{d}	1-3 (highly resistant)
Wairimu dwarf	17.33^{abc}	20.67^{a}	7-9 (high susceptible)
Ciankui	20.00^{a}	19.67^{ab}	7-9 (high susceptible)
GLP 585	8.33^{c}	7.33^{e}	3-5 (resistant)
Miezi mbili	19.00^{ab}	17.33^{bc}	7-9 (high susceptible)
GLP 2 – Susceptible check	16.67^{bc}	17.67^{bc}	5-7 (susceptible)
GLP 1004	6.67^{de}	8.67^{d}	1-3 (highly resistant)
GLP 24	19.00^{ab}	18.33^{b}	7-9 (high susceptible)
GLP 1127	8.00^{c}	8.33^{d}	3-5 (tolerant)
MEAN	8.42	13.22	
CV	19.15	10.53	
LSD	2.72	2.35	
Varieties	*	***	

*Means with the same letters within the column are not significantly different at (p<0.05), * significance at P<0.05, ** significance at P<0.01, *** is significance at P<0.001, scale of 1-9 scores (CIAT, 1978) - (1-3 – highly resistant, 3-5 – resistant/tolerant, 5-7 – susceptible, 7-9 –highly/high susceptible* ensure increased food for farmers for consumption or sold locally to generate income. These findings are in agreement with [13].

Enough bean production for consumption relates to sufficient supply of protein diet and hence malnutrition challenges are avoided and solved. The resistant varieties could also be used by growers to organically grow common beans free from pesticides as they resisted attack from bean stem maggots and also resistance as a trait could form a basis for enhanced bean production [3]. The varieties that farmers could rely upon were Chelalang, Tasha, GLP 1004, KK 8, GLP 585 and KK 15 and GLP 1127.

3.2 Severity and Incidence of Bean Stem Maggot Infestation

Incidence of bean stem maggot infestation was high in Kakamega (8.64), followed by Uasin-Gishu (7.75) and Njoro (7.11). Larvae count was high in Kakamega with a mean of 8.42, then Uasin-Gishu (7.56) and finally Njoro (7.53). Number of pupae count was high in Uasin-Gishu, followed by Kakamega and finally Njoro (Table 2). There was also a site and variety interaction, with bean stem maggot pupae having highest interaction with means of 1.00, larvae had 0.99 and infested plants had 0.4.

The three sites of study were significantly different in response to severity and incidence of bean stem maggot to common bean production. Kakamega had the highest bean stem maggot incidence among the three sites of study. The bean stem maggot incidences being high in Kakamega could be attributed to the fact that, Kakamega has two seasons in a year for planting legumes and therefore since *Ophiomyia spp.* attacks a variety of legumes, the main ones being species of *P. vulgaris* [7], then definitely its population will continue to build up since its lifecycle is very short. Also in warm weather, the eggs hatch within short period of between two to four days but as temperatures drop towards the end of the season, the life cycle takes longer [11]. The total life cycle from egg to adult emergence varies under different environmental conditions [5] and therefore the incidences for the three sites were different. Also, environmental mean square was larger than varieties mean square (Table 2).

Severity cases of bean stem maggot in Njoro, was high and this could be attributed to the type

Table 2. Means of severity and incidence of bean stem maggot in the varieties per plot average

Varieties	No. of infested plants	No. of larvae	No. of pupae
KK 8	7.67[bcd]	6.78[d]	23.11[cd]
Tasha	8.44[bcd]	8.33[abc]	21.33[d]
KK 15 – Resistant control	6.44[d]	6.78[d]	28.22[bcd]
Chelalang	9.33[abc]	7.78[bcd]	23.56[cd]
Wairimu dwarf	3.67[e]	7.44[cd]	46.56[a]
Ciankui	7.78[bcd]	6.78[d]	35.22[abc]
GLP 585	8.11[bcd]	7.78[bcd]	24.33[bcd]
Miezi mbili	6.11[ed]	8.22[abc]	29.67[bcd]
GLP 2 – Susceptible control	11.78[a]	9.22[a]	30.44[bcd]
GLP 1004	6.89[cd]	9.11[ab]	27.56[bcd]
GLP 24	7.89[bcd]	8.56[abc]	35.67[ab]
GLP 1127	9.89[ab]	7.22[cd]	32.22[bcd]
EMS	8.44	2.156	159.06
LSD	2.73	1.38	11.85
KAKAMEGA	8.64[a]	8.42[a]	29.58[a]
NJORO	7.11[b]	7.53[b]	28.83[a]
Uasin-Gishu	7.75[ab]	7.56[b]	31.06[a]
EMS	8.44	2.15	159.06
LSD	1.36	0.69	5.92
Varieties	***	**	*
Environment	0.0886	0.0179	0.7497
Var*Env	0.4056	0.9869	1.0000

Means with the same letters within the column are not significantly different of species of the bean stem maggot, abiotic factors and the fact that Njoro has only one planting season of legumes in a year. The abiotic factors includes: Soil fertility, climate, location and season [14]. Damage is more severe in plants growing under poor conditions such as in infertile soils and drought [3]. Also the population dynamics of bean stem maggot species, composition and patterns of infestation vary with location and season [9]. However, of the three species, *O. phaseoli* and *O. spencerella* are the most important; this is because *O. centrosemantis* only occurs rarely in small numbers [15,16]. Within a growing season, *O. phaseoli* is known to attack the earlier planted crops compared to *O. spencerella* which destroys the late planted crops [17] hence low bean stem maggot infestation because seasonality of occurrence in bean stem maggot species is common [17].

In as much as Njoro had high severity cases of bean stem maggot attack but it was realized that, it had the lowest incidence of larvae and pupae among the three sites. It could also be expected that low population of tryon (*O. phaseoli)* could have resulted from larvae mortality that fed on resistant beans which affected the successful pupation [11].

3.3 Pod Length, Number of Pods per Plant, Plant Height and 100 Seed Weight

The longest pod lengths (cm) were observed in Chelalang, Ciankui and KK 8 common bean varieties with mean values of 12 cm each, while the shortest pod lengths were observed in GLP 1127 and Wairimu dwarf having 8 cm (Table 3). Varieties which had highest number of pods were; KK 8 and GLP 585 with mean of 16 pods per plant and the least number of pods were observed in Miezi mbili variety with mean of 8 pods per plant. The varieties with highest plant height were; Wairimu dwarf and Ciankui bean varieties with mean values of 40 cm each while the least height was observed in Tasha varieties with mean value of 21 cm (Table 3). Chelalang variety had the highest 100 seed weight of mean values of 41.11, and Wairimu dwarf variety had the least with mean values of 23.44. Parameter variations between the different locations are also presented in Table 3.

Pod length and 100 seed weight were significantly different in Kakamega, Njoro and Uasin-Gishu. It was observed that, Chelalang variety had high 1000 seed weight and hence a high yielding variety. The longest pod lengths were observed in Chelalang and KK 8 varieties which were resistant to bean stem maggot pest and also high yielding. This could be because the longer pods had space to accommodate many seeds, the more the number of seeds the more yields expected from the variety and hence more weight. The varieties which had tallest plants by measurements of 40 cm were Wairimu dwarf and Ciankui which are also known to be susceptible to bean fly attack. The Tasha variety was realized to be short with a height of 21 cm, and was also found to be resistant to bean stem maggot attack. Differences in plant height, also affects the expression of resistance to insects; oviposition is greatest on tall plant varieties [18].

Initial plant stand was not significantly different in Western Kenya (Kakamega), Central Rift (Njoro) and North Rift (Uasin-Gishu) at $p<0.05$.This may have been because, the bean seeds had just emerged (germinated) from the soil after getting water from the rains but had not interacted much with soil nutrients, environmental climate, and the pest and diseases (biotic and abiotic factors), hence they were still in their natural normal state [19].

Stand count at 2 weeks and at 4 weeks were significantly different in the three sites at $p<0.05$, this could be attributed due to biotic and the abiotic factors that the common bean plants interact with in the environment. The resistance of plant tissues to insect damage varies markedly during the life of the plant and is age-specific. In some crops, plants are less resistant to insects in the early stages of development [20].

Final plant stand count was significantly different in Central Rift (Njoro) but was not significantly different in Western Kenya (Kakamega) and North Rift (Uasin-Gishu) at $p<0.05$, this might be due to regional location and distance relationship. Western Kenya (Kakamega) and North Rift (Uasin-Gishu) are closer to each other hence may not differ much in their environmental factors and other factors affecting common bean crop like pests and diseases and therefore the two sites are closely related. It was therefore noted from the observation that, Western Kenya (Kakamega) and North Rift (Uasin-Gishu) had higher bean stem maggot infestation than Central Rift (Njoro).

Table 3. Means of grain yield (Kg ha^{-1}) and yield related components of the twelve varieties of common beans within the period of august to December, 2014 across the three sites

Varieties	Pod length (cm)	No. of pods per plant	Plant height	100 Seed weight	Grain yield (Kg ha^{-1})
KK 8	12.11^{a}	16.89^{a}	34.22^{bc}	30.00^{d}	1741.33^{ab}
Tasha	10.67^{b}	10.56^{cde}	21.22^{f}	37.44^{abc}	1675.00^{b}
KK 15 – control	10.44^{cb}	9.11^{de}	28.22^{de}	37.56^{abc}	1833.33^{a}
Chelalang	12.11^{a}	12.56^{bcd}	37.11^{ab}	41.11^{a}	1750.00^{ab}
Wairimu dwarf	8.67^{ed}	16.22^{ab}	40.67^{a}	23.44^{e}	866.67^{e}
Ciankui	12.00^{a}	11.00^{cde}	40.56^{a}	41.00^{a}	1000.00^{d}
GLP 585	9.44^{cd}	16.67^{ab}	31.89^{cd}	36.56^{bc}	1260.00^{cd}
Miezi mbili	7.89^{e}	8.00^{e}	25.56^{ef}	36.78^{bc}	1018.00^{d}
GLP 2 – control	9.33^{cd}	14.11^{abc}	31.89^{cd}	33.56^{cd}	850.33^{e}
GLP 1004	9.67^{cbd}	13.78^{abc}	32.44^{bcd}	31.00^{d}	1323.33^{c}
GLP 24	10.22^{cb}	12.89^{abcd}	37.22^{ab}	39.33^{ab}	1158.33^{cd}
GLP 1127	8.00^{e}	13.44^{abc}	34.67^{bc}	35.33^{bc}	1320.00^{c}
EMS	1.62	19.84	29.82	19.68	125.00
LSD	1.19	4.19	5.13	4.17	8.34

There was no significance different for days to 50% flowering and 75% maturity at $p<0.05$. KK 8 and Wairimu dwarf were the first to attain flowering stage hence early maturing. Chelalang, Tasha and KK 15 varieties were observed to have attained flowering stage late hence late maturing varieties. The resistant check (KK 15) was observed to have determinate growth habit which is characteristic of a bunch and the susceptible variety (GLP 2) to have its growth habit as determinate and indeterminate as classified by CIAT. Wairimu dwarf variety which is susceptible to bean stem maggot (*Ophiomyia* spp.) and low yielding, was found to have indeterminate growth habit.

4. CONCLUSION

The bean varieties that gave positive results of resistance were; Chelalang, Tasha, GLP 1004, KK 8, GLP 585 and KK 15. The tolerant variety was GLP 1127. These varieties also had high grain yields of above 1200 kg^{-1} (Table 3). Therefore these varieties are recommended for small holder farmers to improve bean production in their farms.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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