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EFFECT OF PERCENTAGE TOTAL NITROGEN AND pH ON BLACK APHID INFESTATION LEVELS ON COMMON BEAN VARIETIES INTERCROPPED WITH PESTICIDAL COMPANION CROPS IN KISII COUNTY

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ABSTRACT

Beans (*Phaseolus vulgaris,* L) are among the most important food legume crop in Sub Sahara Africa. Despite its significance both as a food and cash crop, worldwide, yield losses due to insect pest damage, *Aphis fabae,* Scopoli included have been estimated at between 37-100% annually. The yield is generally low, between 0.25 and 0.7 tonnes per hectare compared to world average estimated at over 7 tonnes per hectare. The objectives of the study was to determine the effect of percentage total nitrogen concentration and plant sap pH on aphid infestation levels on common bean varieties intercropped with pesticidal companion plants in Kisii County. Field trials were conducted at Agricultural Training Centre (ATC), Kisii, during the short rain season of 2017, long and short rains of 2018 and long rains of 2019. Three bean varieties (KK8, GLP X 92 and Local variety, Punda) were intercropped with stinging nettle and coriander. Split plot design in three replications was used. Pure stand common bean plots were established as control with positive being sprayed using a chemical pesticide (lambdacyhalothrin) and negative not sprayed. Ten bean, ten stinging nettle and ten coriander plants per plot were randomly sampled for aphid infestation on weekly basis. Bean, stinging nettle and coriander leaf samples were harvested, oven-dried, weighed, ground and Nitrogen percentage determined using the Digestion and spectrophotometer methods. Similarly, plant sap pH was determined using pH meter in water suspension. Data obtained was subjected to Analysis of Variance to determine mean aphid incidence & severity, pH and total percentage Nitrogen. LSD was used to separate means at $P<0.05$ level of probability. Correlation was done to establish the relationship between incidence and severity of *A. fabae* with Nitrogen concentration and pH. There was significant ($P<0.05$) difference in leaf and stem incidence among varieties during all seasons. Highest incidence was observed on stinging nettle leaves (0.852, SR 2018). Aphid incidence was highest on leaves in LR-2018 (PUNDA-VE, 0.463) and lowest on stems (coriander, 0.002) in SR-2017. Significant difference in plant total nitrogen was noted among different varieties in LR 2018 with highest percentage Nitrogen (4.32%) recorded in LR-2019 on variety KK8 both in pure stand and intercrop and lowest (2.21%) observed on coriander during the SR 2017 season. Nitrogen concentration significantly differed with crop stage during LR of 2017 and 2018 with vegetative stage being the highest at 3.84 % in LR of 2019. Plant sap pH significantly differed among varieties in all seasons with the highest being stinging nettle (8.63) in LR 2019 and lowest (5.33) on GLP92 in LR 2018. Genstat software version 14 was used.

Key words: *Phaseolus vulgaris*, Varieties, *Urtica dioica*, *Coriandrum sativum, Aphis fabae*, Incidence, Severity, Nitrogen and pH.

INTRODUCTION

Common bean (*Phaseolus vulgaris* L) is among grain legumes that are commonly grown worldwide thus plays a key role as a food staple and cash crop (FAOSTAT, 2014; Nassary et al., 2020). Farmers prefer common bean because of its fast maturing characteristics that assures households of timely food security and income (Legesse et al., 2006).The increase in the world's population by 2050 is projected to be around 9.1 billion (34% higher than today), and food production will need to increase by 70% (Loboguerrero et al., 2019; Stagnari et al., 2017). This projection indicates that more food is to be produced using less land against an ever increasing population (FAO, 2009) as is the case in sub-Saharan Africa (SSA) where common bean production by smallholder producers is common (FAO statistics, 2016; Diana et al., 2019; Badu-Apraku and Fakorede, 2017).

The pulse is important for the human dietary protein, complex carbohydrates, vitamins, minerals and dietary fibre requirements (Nkhata et al., 2021; Rurangwa, et al., 2018; Mwanauta et al., 2015; Cortes *et al*., 2013). The legume provides edible leaves, seeds and pods as vegetables (Mamiro et al., 2012; Nedumaran et al., 2015). When beans are consumed with carbohydrate staples (maize, rice and cassava), the mixture provides a balanced diet (Akibode and Maredia, 2011) thus meeting the requirements of the first three Sustainable Development Goals (SDGs) which address food security for all (Mensi and Udenigwe, 2021).

According to FAO statistics *P. vulgaris* is globally grown on nearly 28 million hectares producing about 20 million tonnes of grains (Gupta et al., 2019). Across the SSA region Kenya included, common bean has an average yield gap of 2.6 tonnes Ha^{-1} (van Loon et al., 2018). In Kenya the legume is grown on an estimated area of over 500,000 hectares of land (Barkutwo et al., 2020; Kihara et al., 2016).

Common bean per capita consumption in Kenya is as high as 50 to 66 kg per year and is cheap source of protein especially among low-income households who cannot afford more nutritious food stuffs such as meat and fish (Nedumaran, 2015; Beebe *et al*., 2013). However, the yield of this pulse is constrained by insect pest infestation, poor soil fertility with little or no use of fertilizers, intercropping with competitive crops, periodic water stress, weed competition, continuous use of varieties with low genetic potential and high incidences of diseases (Otieno et al., 2020; Blackman and Eastop, 2017). Actual yield of approximately 250 kg per hectare are achieved when intercropped and 700 kg per hectare are realized in pure stands under farmer management conditions (FAOSTAT, 2016). These yields are lower compared to world average estimated at over 7000 kg/ha and are not commensurate with the high per capita consumption in Kenya (Muthoni et al., 2017; Baijukya et al., 2016).

MATERIALS AND METHODS

The study was conducted at the Agricultural Training Centre (ATC), Kisii in the County Government of Kisii. The ATC is located in Lower Highland (LHI) Agro-ecological Zone (AEZ) at latitude 0^0 40' 38.4"S and longitude 34^0 46' 57" E and at an altitude of 1694.13 m.a.s.l (Jaetzold *et al*., 2009). The area has a highland equatorial climate resulting into two rainy seasons, the long rains occurring between February and June, and short rains coming between September and early December. The area receives an average annual rainfall of 1500mm.

Maximum temperatures range between 21°C–30°C, while minimum temperatures range between 15°C–20°C (Jaetzold *et al*., 2009). The soils are red volcanic soils (nitosols) which are well drained and extremely deep (Jaetzold *et al*., 2009).

The trials were conducted during the short rain season of 2017, long and short rain seasons of 2018 and long rain season of 2019. Plots measuring 3m x 3m were set up and given treatments in Split Plot Design replicated three times. Plots within blocks were separated by 0.5 m wide alleys while blocks were 1m apart. Components in plot treatments included three bean varieties (KK8, GLP X92 and Local variety, Punda), Coriander (*Coriandrum sativum*) and Stinging nettle (*Urtica dioica*). Bean varieties in pure stand served as control plots. Whereas the positive control plots were sprayed with chemical pesticide (lambdacyhalothrin), the negative control plots were not.

Common bean, stinging nettle and coriander plots: Each plot was planted with two rows of stinging nettle, one on either side of the plot with intra-row spacing of 50cm. Four rows of common beans (45cm x 15 cm) alternating with three rows of coriander (intra-row spacing of 10 cm) were planted between two rows of stinging nettle.

Common bean and stinging nettle plots: Each plot was planted with two rows of stinging nettle (intra-row spacing of 50cm). Four rows of common beans (45cm x 15 cm) were planted between two rows of stinging nettle.

Common bean and coriander plots: Five rows of common beans (spacing 45cm x 15 cm) alternated with four rows of coriander (intra-row spacing of 10 cm).

Pure common bean (Control) plots: Five rows of common beans (spacing 45cm x 15 cm) were planted in each plot. One set of plots served as positive controls while the other as negative control. The positive control plot was spayed with chemical insecticide while the negative control shall remain unsprayed.

Sampling procedures

Sampling was done on weekly basis starting when bean plants were two weeks old and continued till physiological maturity.

Determination of aphid incidence and severity

Ten common bean, ten stinging nettle and ten coriander plants per plot were randomly sampled for aphid infestation (leaf & stem incidence and leaf & stem severity). Incidence (plants with pest or symptoms) was expressed as a percentage of all the sampled plnts (plants with aphid infestation over total number of plants sampled per field x 100). Aphid severity rating (degree of damage symptom or infestation level observed per plant) was based on number of aphids per plant per field on the scale rating of 1 to 5 (Ogecha et al., 2019) where;
1 = no damage and infestation
2 = light damage and infestation <5% plant parts damaged or infested by pest
3 = average damage and infestation >5 and <50% plant parts damaged
4 = considerable damage and infestation >50% plants parts damaged and severe stunting or wilting

5 = Plants with very high infestation levels and severity of damage or wilted and dead plants

Determination of total nitrogen in beans, stinging nettle and coriander leaves

Leaves/branches from ten plants of each type were picked randomly from each plot and placed in paper bags. Collected plant samples were washed using clean tap water and oven dried to a constant weight at 70^0 C for 24 hours (Houba et. al., 1995). The dry weight of the sample was determined and recorded. Weighed, oven-dry samples were ground to powder using hammer mills to pass through a 2mm mesh. About 0.3g of the dried ground plant sample was weighed in a metal weighing funnel and transferred to a digestion tube. 2.5ml. of the digestion mixture (Salycilic acid and Sulphuric acid-Selenium mixture) was added.

The digestion tube was placed in heating block and heated at 100^0 C for about 2 hours. The tube was removed, allowed to cool and three 1-ml aliquots of hydrogen peroxide added successively.

The tube was again placed in the preheated block and heated at 330^{0}C for 2 hours until the digests turned colourless or light-yellow. The tube was removed from the block and cooled to room temperature. 48.3 ml of water was added to the contents of the tube and mixing done. This was allowed to stand overnight and again swirled for thorough mixing to be achieved. The digests were then transferred to a test tube and let to settle (Novozamsky, *et al*.1983).

Total Nitrogen in the plant samples was determined using calorimetric method. Blank and sample digests were diluted with water [1+9 (v/v)]. 0.2ml of the diluted blank and sample digests were pipetted into test tubes. 3.0 ml. of mixed reagent I (Salicylate, nitroprusside and EDTA solutions) were added into each test tube and swirled to mix. Then 5.0 ml. of mixed reagent II (Buffer and hypochlorite solutions) was added andgently shaken. These were allowed to stand for 2 hours. Absorbance was then measured in a 1-cm cuvette at a wavelength of 660nm using spectrophotometry method. Using standard curve N concentration was read against the recorded absorbance (Novozamsky *et al*. 1974).

Calculation

The nitrogen contencentration of the dried plant material expressed in % N was calculated by:

N % = (a-b) x v x100/1000 x w x al. x 1000

Where:

a is the concentration of nitrogen in the sample digest, in mg/L;

b is the concentration of nitrogen in the blank digest, in mg/L;

v is the total volume of the digest at the end of the analysis procedure, in ml;

w is the weight of plant material sample, in g.

al. is aliquot of the solution taken in ml

Determination of sap pH of beans, stinging nettle and coriander

Oven-dried leaf samples were ground to powder using hammer mills to pass through a 2mm mesh. Distilled water was added to the ground sample to give an 8:1 volume ratio of water to leaf sample (Cornelissen et al., 2006). Samples were then shaken in a laboratory rotary shaker for 1 hour then centrifuging done until there was a clear separation of the sediment and the supernatant. Supernatant was then measured for pH using an adequately calibrated pH meter.

Data Analysis: Data obtained was subjected to Analysis of Variance (ANOVA) to determine mean aphid incidence/severity, Nitrogen concentration and pH in beans, stinging nettle and coriander. LSD was used to separate means at P<0.05 level of probability. Correlation was done to establish the relationship between incidence and severity of *Aphis fabae* with total Nitrogen concentration and plant sap pH. Genstat software version 14 was used.

RESULTS

Effect of variety on aphid leaf incidence

There was significant ($P<0.05$) difference in leaf incidence among varieties during all seasons. Highest and lowest incidence was observed in stinging nettle (leaf incidence of 0.852, SR 2018) and coriander (stem incidence of 0.002, SR 2017) respectively. The three positive (spayed) and negative (not sprayed) pure bean stand controls significantly ($P<0.05$) differed in leaf aphid incidence in most of the seasons. A part from SR 2017, leaf aphid incidence in intercrops of stinging nettle, coriander or a combination of both significantly ($P<0.05$) differed from that of unsprayed pure bean plots for all varieties in all the other seasons.

Key: Abbreviations and interpretation for plot treatments

Variety/Treatment	Interpretation
GLP92+VE	GLPX92 pure stand and sprayed
GLP92-VE	GLPX92 pure stand and unsprayed
GLP92C	GLP X92 intercropped with coriander
GLP92N	GLPX92 intercropped with stinging nettle
GLP92NC	GLPX92 intercropped with stinging nettle and coriander
KK8+VE	KK8 in pure stand and sprayed
KK8-VE	KK8 in pure stand and unsprayed
KK8C	KK8 intercropped with coriander
KK8N	KK8 intercropped with stinging nettle
KK8NC	KK8 intercropped with stinging nettle and coriander
PUNDA+VE	punda in pure stand and sprayed
PUNDA-VE	punda in pure stand and unsprayed
PUNDAC	punda intercropped with coriander
PUNDAN	punda intercropped with stinging nettle
PUNDANC	punda intercropped with stinging nettle and coriander
NETTLE	stinging nettle plants
CORIANDER	coriander plants

Table 1-Effect of variety on aphid leaf incidence during SR 2017, LR and SR 2018 and LR 2019

Variety/Treatment	Short Rains 2017	Long Rains 2018	Short Rains 2018	Long Rains 2019
GLP92+VE	0.119^{ab}	0.000^{h}	0.025^{i}	0.00^{d}
GLP92-VE	0.379^{b}	0.379^{c}	0.404^{b}	0.368^{b}
GLP92C	0.256^{b}	0.256^{d}	0.256^{c}	0.249^{c}
GLP92N	0.252^{b}	0.284^{d}	0.226^{d}	0.275^{c}
GLP92NC	0.250^{b}	0.208^{e}	0.150^{f}	0.201^{c}
KK8+VE	0.021^{ab}	0.026^{h}	0.000^{j}	0.025^{d}
KK8-VE	0.392^{b}	0.447^{b}	0.182^{e}	0.433^{b}
KK8C	0.143^{ab}	0.230^{e}	0.125^{g}	0.223^{c}
KK8N	0.224^{b}	0.225^{d}	0.100^{h}	0.218^{c}
KK8NC	0.149^{ab}	0.159^{f}	0.125^{g}	0.154^{c}
PUNDA+VE	0.086^{ab}	0.090^{g}	0.033^{i}	0.087^{d}
PUNDA-VE	0.404^{b}	0.463^{b}	0.387^{b}	0.449^{b}
PUNDAC	0.189^{ab}	0.146^{f}	0.164^{f}	0.142^{c}
PUNDAN	0.196^{ab}	0.198^{e}	0.188^{e}	0.192^{c}
PUNDANC	0.099^{ab}	0.140^{e}	0.204^{e}	0.136^{c}
NETTLE	0.815^{a}	0.818^{a}	0.852^{a}	0.794^{a}
CORIANDER	0.006^{c}	0.038^{h}	0.017^{i}	0.037^{d}
P	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD	**0.1803**	**0.2761**	**0.2122**	**0.1943**

Means with the same alphabetical letter within a column are not significantly different at 5% probability using LSD value

Effect of variety on aphid stem incidence

There was significant (P<0.05) difference in stem incidence among varieties during all seasons. Highest stem incidence was (0.810) on stinging nettle in the short rains of 2017 and lowest on spayed GLP92 variety (GLP92+VE, 0.000) in all the seasons except short rains of 2017.

Table 2-Effect of variety on aphid stem incidence during SR 2017, LR and SR 2018 and LR 2019

Variety/Treatment	**Short Rains 2017**	**Long Rains 2018**	**Short Rains 2018**	**Long Rains 2019**
GLP92+VE	0.112^{c}	0.000^{d}	0.000^{g}	0.000^{c}
GLP92-VE	0.358^{b}	0.358^{b}	0.283^{c}	0.348^{b}
GLP92C	0.274^{b}	0.274^{b}	0.242^{d}	0.265^{b}
GLP92N	0.239^{b}	0.299^{b}	0.216^{e}	0.291^{b}
GLP92NC	0.217^{b}	0.114^{d}	0.160^{f}	0.111^{c}
KK8+VE	0.217^{b}	0.050^{d}	0.000^{j}	0.049^{c}
KK8-VE	0.354^{b}	0.337^{b}	0.129^{f}	0.327^{b}
KK8C	0.461^{b}	0.068^{d}	0.144^{f}	0.065^{c}
KK8N	0.200^{b}	0.225^{c}	0.050^{g}	0.218^{b}
KK8NC	0.111^{c}	0.124^{d}	0.087^{g}	0.121^{c}
PUNDA+VE	0.100^{c}	0.110^{d}	0.049^{i}	0.107^{c}
PUNDA-VE	0.373^{b}	0.356^{b}	0.336^{b}	0.345^{b}
PUNDAC	0.178^{c}	0.185^{c}	0.153^{f}	0.179^{c}
PUNDAN	0.136^{c}	0.133^{c}	0.150^{f}	0.129^{c}
PUNDANC	0.048^{c}	0.071^{d}	0.148^{f}	0.068^{c}
NETTLE	0.810^{a}	0.808a	0.763^{a}	0.784^{a}
CORIANDER	0.002^{c}	0.092^{d}	0.018^{g}	0.011^{c}
P	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD	**0.2703**	**0.2708**	**0.2881**	**0.1900**

Means with the same alphabetical letter within a column are not significantly different at 5% probability using LSD value

Effect of variety on aphid leaf severity

There was significant (P<0.05) difference in leaf severity among varieties during all seasons. Stinging nettle had the highest leaf severity of 3.460 during 2018 short rains. Severity on sprayed variety GLP92 (GLP92+VE, 1.000) was the lowest in long rains of 2018, followed by coriander with leaf density of 1.006 in the SR of 2017. Positive and negative controls for the three varieties showed significant (P<0.05) difference in severity in all the seasons. A combination of PUNDA beans, stinging nettle and coriander intercrop recorded the lowest severity (1.062) compared to similarly combinations of other bean varieties.

Table 3-Effect of variety on aphid leaf severity during SR 2017, LR and SR 2018 and LR 2019

Variety/Treatment	Short Rains 2017	Long Rains 2018	Short Rains 2018	Long Rains 2019
GLP92+VE	1.148[c]	1.000[c]	1.025[c]	1.097[c]
GLP92-VE	1.681[b]	1.701[b]	1.931[b]	1.631[b]
GLP92C	1.335[b]	1.340[b]	1.376[c]	1.295[c]
GLP92N	1.260[b]	1.336[b]	1.260[c]	1.296[c]
GLP92NC	1.202[c]	1.233[c]	1.127[c]	1.196[c]
KK8+VE	1.021[c]	1.021[c]	1.000[c]	1.099[c]
KK8-VE	1.624[b]	1.744[b]	1.637[b]	1.691[b]
KK8C	1.157[c]	1.225[c]	1.157[c]	1.188[c]
KK8N	1.230[b]	1.250[c]	1.175[c]	1.212[c]
KK8NC	1.161[c]	1.195[c]	1.117[c]	1.196[c]
PUNDA+VE	1.092[c]	1.119[c]	1.103[c]	1.086[c]
PUNDA-VE	1.665[b]	1.790[b]	1.812[b]	1.736[b]
PUNDAC	1.212[b]	1.244[c]	1.187[c]	1.207[c]
PUNDAN	1.204[c]	1.254[c]	1.200[c]	1.217[c]
PUNDANC	1.062[c]	1.163[c]	1.137[c]	1.128[c]
NETTLE	3.241[a]	3.451[a]	3.460[a]	3.348[a]
CORIANDER	1.006[c]	1.073[c]	1.032[c]	1.041[c]
P	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD	**0.3719**	**0.3818**	**0.4820**	**0.3704**

Means with the same alphabetical letter within a column are not significantly different at 5% probability using LSD value

Effect of variety on aphid stem severity

There was significant ($P<0.05$) difference in stem severity among varieties during all seasons. In all the seasons except short rains of 2018 (1.135), stinging nettle had the highest severity of over 2.3. Severity on sprayed GLP92 variety (GLP92+VE) was the lowest (1.000) during the 2018 rain seasons followed by coriander (1.006) during the short rains of 2017.

Table 4-Effect of variety on aphid stem severity during SR 2017, LR and SR 2018 and LR 2019

Variety/Treatment	**Short Rains 2017**	**Long Rains 2018**	**Short Rains 2018**	**Long Rains 2019**
GLP92+VE	1.125[c]	1.000[c]	1.000[b]	1.097[d]
GLP92-VE	1.579[b]	1.579[b]	1.579[a]	1.532[b]
GLP92C	1.353[b]	1.353[b]	1.347[a]	1.313[c]
GLP92N	1.333[b]	1.441[b]	1.333[a]	1.398[c]
GLP92NC	1.246[c]	1.208[b]	1.225[b]	1.172[d]
KK8+VE	1.031[c]	1.034[c]	1.000[b]	1.003[d]
KK8-VE	1.448[b]	1.471[b]	1.617[a]	1.423[b]
KK8C	1.224[c]	1.468[b]	1.231[b]	1.122[d]
KK8N	1.206[c]	1.230[b]	1.087[b]	1.194[d]
KK8NC	1.118[c]	1.118[c]	1.093[b]	1.084[d]
PUNDA+VE	1.115[c]	1.120[c]	1.119[b]	1.086[d]
PUNDA-VE	1.504[b]	1.829[b]	1.116[b]	1.774[b]
PUNDAC	1.363[b]	1.402[b]	1.725[a]	1.360[c]
PUNDAN	1.135[c]	1.185[c]	1.281[b]	1.150[d]
PUNDANC	1.035[c]	1.077[c]	1.044[b]	1.044[d]
NETTLE	2.355[a]	2.617[a]	1.135[b]	2.538[a]
CORIANDER	1.006[c]	1.015[c]	1.034[b]	1.099[d]
P	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD	**0.2888**	**0.3833**	**0.4418**	**0.3718**

Means with the same alphabetical letter within a column are not significantly different at 5% probability using LSD value

Comparison between leaf and stem incidence

Aphid leaf and stem incidence differed significantly ($P<0.05$) in all the seasons. Highest incidence (0.852) was observed on stinging nettle leaves (NETTLE-L) in the 2018 short rains. Among the three bean varieties, unsprayed Punda leaves in pure stand (PUNDA-VE-L) had an incidence of 0.463 being the highest. Leaves and stems of sprayed variety GLP92 (GLP92+VE-L and GLP92+VE-S) recorded 0.000 incidence in all the seasons except short rains of 2017.

Table 5: Comparison between leaf and stem incidence during SR 2017, LR 2018, SR 2018 and LR 2019

Variety/Treatment	Short Rains 2017	Long Rains 2018	Short Rains 2018	Long Rains 2019
GLP92+VE-L	0.119c	0.000d	0.025c	0.000d
GLP92+VE-S	0.112c	0.000d	0.000c	0.000d
GLP92-VE-L	0.379b	0.379b	0.404b	0.368b
GLP92-VE-S	0.358b	0.358b	0.283b	0.348b
GLP92C-L	0.256b	0.256b	0.267b	0.249b
GLP92C-S	0.274b	0.274b	0.170b	0.265b
GLP92N-L	0.252b	0.284b	0.226b	0.275b
GLP92N-S	0.239b	0.299b	0.216b	0.291b
GLP92NC-L	0.250b	0.208c	0.150b	0.201c
GLP92NC-S	0.217c	0.114c	0.160b	0.111c
KK8+VE-L	0.021c	0.026c	0.000c	0.025d
KK8+VE-S	0.025c	0.050c	0.000c	0.048c
KK8-VE-L	0.392b	0.447b	0.182b	0.433b
KK8-VE-S	0.354b	0.337b	0.129b	0.327b
KK8C-L	0.143c	0.230c	0.125b	0.223c
KK8C-S	0.461b	0.068c	0.192b	0.102c
KK8N-L	0.224c	0.225c	0.100b	0.218c
KK8N-S	0.200c	0.225c	0.050c	0.218c
KK8NC-L	0.149c	0.159c	0.125b	0.154c
KK8NC-S	0.111c	0.124c	0.087b	0.145c
PUNDA+VE-L	0.086c	0.090c	0.033c	0.087c
PUNDA+VE-S	0.100c	0.110c	0.049c	0.107c
PUNDA-VE-L	0.404b	0.463b	0.387b	0.449b
PUNDA-VE-S	0.373b	0.356b	0.336b	0.345b
PUNDAC-L	0.189c	0.146c	0.164b	0.142c
PUNDAC-S	0.178c	0.185c	0.153b	0.179c
PUNDAN-L	0.196c	0.198c	0.188b	0.192c
PUNDAN-S	0.136c	0.133c	0.150c	0.129c
PUNDANC-L	0.099c	0.140c	0.204b	0.136c
PUNDANC-S	0.048c	0.071c	0.148b	0.068c
NETTLE-L	0.815a	0.818a	0.852a	0.794a
NETTLE-S	0.810a	0.808a	0.763a	0.784a
CORIANDER-L	0.006c	0.038c	0.017c	0.037c
CORIANDER-S	0.002c	0.011d	0.011c	0.011d
P	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD	**0.2276**	**0.1963**	**0.3351**	**0.1903**

Key: L, means leaves and S, means stems

Comparison between leaf and stem severity

There was significant difference in severity ($P<0.05$) among varieties throught the whole experimental period. Stinging nettle leaves had the highest aphid severity/density of 3.460 in the short rains of 2018. The lowest (1.000) severity was on sprayed leaves and stems of variety GLP92 (GLP92+VE-L and GLP92+VE-S) in all the seasons except short rains of 2017.

Table 6: Comparison between leaf and stem severity during SR 2017, LR 2018, SR 2018 and LR 2019

Variety/Treatment	Short Rains 2017	Long Rains 2018	Short Rains 2018	Long Rains 2019
GLP92+VE-L	1.148e	1.000e	1.025d	1.000e
GLP92+VE-S	1.125e	1.000e	1.000d	1.097d
GLP92-VE-L	1.681c	1.681c	1.931c	1.638c
GLP92-VE-S	1.579c	1.579c	1.579c	1.564c
GLP92C-L	1.335d	1.335d	1.376d	1.295d
GLP92C-S	1.353c	1.353d	1.347d	1.313d
GLP92N-L	1.260d	1.336d	1.260d	1.296d
GLP92N-S	1.333d	1.441d	1.333d	1.398d
GLP92NC-L	1.202d	1.233d	1.127d	1.196d
GLP92NC-S	1.246d	1.208d	1.225d	1.204d
KK8+VE-L	1.021d	1.021e	1.000d	1.006e
KK8+VE-S	1.031d	1.034d	1.000d	1.098d
KK8-VE-L	1.624c	1.744c	1.637c	1.691c
KK8-VE-S	1.448c	1.468c	1.617c	1.423c
KK8C-L	1.157e	1.225d	1.157d	1.188d
KK8C-S	1.224d	1.156d	1.231d	1.153d
KK8N-L	1.230d	1.250d	1.175d	1.220d
KK8N-S	1.206d	1.230d	1.087d	1.225d
KK8NC-L	1.161e	1.195d	1.117d	1.159d
KK8NC-S	1.118e	1.118d	1.093d	1.116d
PUNDA+VE-L	1.092e	1.119d	1.103d	1.101d
PUNDA+VE-S	1.115e	1.120d	1.041d	1.118d
PUNDA-VE-L	1.665c	1.790c	1.812c	1.743c
PUNDA-VE-S	1.504c	1.829c	1.725c	1.806c
PUNDAC-L	1.212d	1.244d	1.187d	1.214d
PUNDAC-S	1.363c	1.402d	1.281d	1.391d
PUNDAN-L	1.204d	1.254d	1.200d	1.224d
PUNDAN-S	1.135e	1.185d	1.137d	1.182d
PUNDANC-L	1.062e	1.163d	1.137d	1.143d
PUNDANC-S	1.035e	1.077d	1.044d	1.108d
NETTLE-L	3.241a	3.451a	3.460a	3.348a
NETTLE-S	2.355b	2.617b	2.419b	2.408b
CORIANDER-L	1.006e	1.073d	1.032d	1.051d
CORIANDER-S	1.006e	1.015e	1.013d	1.069d
P	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD	**0.3290**	**0.3791**	**0.4419**	**0.3854**

Effect of variety on plant total percentage Nitrogen: It was only during the long rain season of 2018 that significant (P<0.05) difference in plant total nitrogen was noted among different varieties. Highest percentage Nitrogen (4.32%) was recorded in 2019 long rains on variety KK8 both in pure stand and intercrop and lowest (2.21%) observed on coriander during the SR 2017 season.

Table 7-Effect of variety on plant total percentage Nitrogen during SR 2017, LR and SR 2018 and LR 2019

Variety/Treatment	Short Rains 2017	Long Rains 2018	Short Rains 2018	Long Rains 2019
GLP92+VE	2.61^{a}	3.03^{b}	2.79^{a}	3.56^{a}
GLP92-VE	2.61^{a}	3.03^{b}	2.79^{a}	3.56^{a}
GLP92C	2.61^{a}	3.03^{b}	2.79^{a}	3.56^{a}
GLP92N	2.61^{a}	3.03^{b}	2.79^{a}	3.56^{a}
GLP92NC	2.61^{a}	3.03^{b}	2.79^{a}	3.56^{a}
KK8+VE	3.11^{a}	2.68^{b}	3.11^{a}	4.32^{a}
KK8-VE	3.11^{a}	2.68^{b}	3.11^{a}	4.32^{a}
KK8C	3.11^{a}	2.68^{b}	3.11^{a}	4.32^{a}
KK8N	3.11^{a}	2.68^{b}	3.11^{a}	4.32^{a}
KK8NC	3.11^{a}	2.68^{b}	3.11^{a}	4.32^{a}
PUNDA+VE	2.95^{a}	4.08^{a}	3.02^{a}	3.17^{a}
PUNDA-VE	2.95^{a}	4.08^{a}	3.02^{a}	3.17^{a}
PUNDAC	2.95^{a}	4.08^{a}	3.02^{a}	3.17^{a}
PUNDAN	2.95^{a}	4.08^{a}	3.02^{a}	3.17^{a}
PUNDANC	2.95^{a}	4.08^{a}	3.02^{a}	3.17^{a}
NETTLE	2.45^{a}	2.68^{b}	2.67^{a}	2.93^{a}
CORIANDER	2.21^{a}	2.99^{b}	2.55a	3.56^{a}
P	**0.989**	**<0.001**	**0.999**	**0.221**
LSD	**1.468**	**0.7868**	**1.260**	**1.412**

Effect of crop stage on plant total Nitrogen percentage:

Total percentage Nitrogen significantly (P<0.05) differed with crop stage during the short rain seasons of 2017 and 2018. In both cases Nitrogen percentage in vegetative and maturity stages was higher than that of flowering/podding. During the long rains of 2018 and 2019 there were differences in total N% which were not significant.

Table 8: Effect of crop stage on plant total Nitrogen percentage during SR 2017, LR and SR 2018 and LR 2019

Crop Stage	Short Rains 2017	Long Rains 2018	Short Rains 2018	Long Rains 2019
VEGETATIVE	3.435[a]	3.280[a]	3.445[a]	3.84[a]
FLOWERING/PODDING	1.564[b]	3.119[a]	1.821[b]	3.44[a]
MATURITY	3.187[a]	3.119[a]	3.320[a]	3.34[a]
P	**<0.001**	**0.534**	**<0.001**	**0.165**
LSD	**0.3398**	**0.4633**	**0.2397**	**0.545**

Effect of plant variety on pH: Plant pH consistently showed significant difference (P<0.05) among varieties in all the seasons, with that of stinging nettle being the highest throught with a peak of 8.63 in long rains of 2019.

Table 9-Effect of variety on pH during SR 2017, LR and SR 2018 and LR 2019

Variety/Treatment	Short Rains 2017	Long Rains 2018	Short Rains 2018	Long Rains 2019
GLP92+VE	6.01[b]	5.33[c]	6.06[b]	5.79[c]
GLP92-VE	6.01[b]	5.33[c]	6.06[b]	5.79[c]
GLP92C	6.01[b]	5.33[c]	6.06[b]	5.79[c]
GLP92N	6.01[b]	5.33[c]	6.06[b]	5.79[c]
GLP92NC	6.01[b]	5.33[c]	6.06[b]	5.79[c]
KK8+VE	6.06[b]	5.35[c]	6.13[b]	5.89[c]
KK8-VE	6.06[b]	5.35[c]	6.13[b]	5.89[c]
KK8C	6.06[b]	5.35[c]	6.13[b]	5.89[c]
KK8N	6.06[b]	5.35[c]	6.13[b]	5.89[c]
KK8NC	6.06[b]	5.35[c]	6.13[b]	5.89[c]
PUNDA+VE	5.98[b]	5.63[b]	5.94[b]	6.16[b]
PUNDA-VE	5.98[b]	5.63[b]	5.94[b]	6.16[b]
PUNDAC	5.98[b]	5.63[b]	5.94[b]	6.16[b]
PUNDAN	5.98[b]	5.63[b]	5.94[b]	6.16[b]
PUNDANC	5.98[b]	5.63[b]	5.94[b]	6.16[b]
NETTLE	7.723[a]	8.44[a]	7.99[a]	8.63[a]
CORIANDER	5.95[b]	6.33[b]	5.99[b]	6.00[b]
P	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD	**0.3214**	**0.6850**	**0.3519**	**0.2665**

Effect of crop stage on plant pH: Crop stage had no significant (P>0.05) effect on pH.

Table 10: Effect of crop stage on plant pH during SR 2017, LR and SR 2018 and LR 2019

Crop stage	Short Rains 2017	Long Rains 2018	Short Rains 2018	Long Rains 2019
VEGETATIVE	6.387[a]	5.80[a]	6.431[a]	6.21[a]
FLOWERING/PODDING	6.209[a]	5.85[a]	6.281[a]	6.18[a]
MATURITY	6.152[a]	6.34[a]	6.237[a]	6.76[a]
P	**0.472**	**0.244**	**0.672**	**0.061**
LSD	**0.3980**	**0.703**	**0.4560**	**0.607**

DISCUSSIONS

Significant difference in leaf and stem incidence (Table 1 and 2) among varieties meant that aphids had more preference for some varieties than others. Similar trend was observed in leaf and stem severity levels (Table 3 and 4) in most seasons. Stinging nettle with the highest leaf aphid incidence (0.852, SR-2018) and severity (3.46, SR-2018) was the most preferred species compared to all the three bean varieties (GLPX92, KK8, PUNDA) and coriander. The unmatched attraction of aphids to stinging nettle was probably due to a number of factors including better nutritive value of the plant which is in agreement with the report of Ben et al. (2017) which states that aphids multiply exponentially on nitrogen rich host plants. This concurs with the findings of Alhmedi et al. (2009) that stinging nettle is a good food resource for many insect pests and their predators. Coriander remained almost uninfested by aphids (Table 2, incidence of 0.002 and Table 3, severity of 1.006, SR-2017) most likely because of its strong aromatic and fragrant tendencies, which possibly repelled aphids away from the fields and attracted their predators (lady bird beetle) to feed on them. This is supported by Togni et al. (2016) who established that coriander at all vegetative stages, emits volaties that are attractive to natural enemies of aphids. In addition, coriander flowers serve as source of nector and pollen to aphid predators according to the study of Salamanca et al. (2015). The predators such as lady bird beetles fed on the aphids subsequently reducing their numbers on coriander. Sharma and Meena (2019) demonstrated that there is always a higher number of hoverflies feeding on aphids on coriander especially during prolonged flowering time therefore suggesting a positive correlation between coriander flowers and the biological control agents.

Differences in aphid infestation levels on bean varieties KK8, GLPX92 and Punda could be related to their respective varietal characteristics which include insect pest resistance, which is in tandem with the work of Meradsi. (2017). This consensus is based on the fact that insects show a marked preference for certain cultivars than others within a species as evidenced by differences in aphid incidence and severity among the different common bean varieties (Tables 1, 2, 3 and 4) . For example in the short rains of 2018, there was significant difference in leaf aphid incidence between PUNDA-VE (0.387) and KK8-VE (0.182) (Table 1). Other probable reason for diffences in bean cultivar aphid infestation could be attributed to the presence of different concentrations of plant compounds including amino acids, phenolics and hydroxamic acids. These compounds are thought to account for varying levels of cultivar tolerance as demonstrated by Caretto et al. (2015). Phenolics and hydroxamic acids are used to attract or repell different organisms as per plants benefit. There is likelihood that these compounds protected some common bean varieties by acting as inhibitors and toxicants against the black bean aphids. Similar sentiments in earlier studies were shared by Bhattacharya et al. (2010) who explained variations in aphid infestation on common bean cultivars. Similarly, Silva et al. (2016) reported that bean varieties with different tolerance levels to various biotic constraints including aphids have been developed to reduce insect herbivore damage as seen on the low aphid incidence on common beans variety GLPX92NC compared to similar treatments on varieties KK8NC and PUNDANC (Table 1). The general low *Aphis fabae* incidence and severity on common bean varieties compared to stinging nettle, might be due to the influence of volatiles released from coriander that repelled (pushed away) them from the common bean plots and were in turn attracted to volatiles from stinging nettle (pulled to).

Significant differences in aphid infestation on leaf and stem organs were noted in all seasons. For instance, during the long rain season of 2019 leaf and stem incidence for coriander and positive control of KK8 bean variety were; CORIANDER-L (0.037), CORIANDER-S (0.11), KK8+VE-L (0.025) and KK8+VE-S (0.048) (Table 5). Similar observation was made on significant differences leaf and stem severity in LR 2018 where CORIANDER-L recorded (1.073) and CORIANDER-S (1.015) (Table 6). There is likelihood that these results corresponded to differences in nutrient distribution especially nitrogen in the various plant organs. This observation is supported by Wang and Ruan, 2016 who found out that concentration of soluble nitrogen varies among plant tissues and organs, being higher in structures such as flowers, pollen and leaves, than in the xylem and phloem. Likewise, Shah. (2017) argued that plant structures with high nitrogen levels may attract a greater density of insects compared to those with lower nitrogen concentration. Djumaeva et al. (2012) is in support of this finding and explains that the relative chlorophyll content (RCC) in plant leaves is a powerful indicator of foliar nitrogen content. Similarly, Souza et al., 2011 demonstrated that chlorophyll which contains nitrogen is in higher concentration in leaves compared to stems. This could be an influencing factor in higher aphid infestation on leaves (NETTLE-L) compared to stems (NETTLE-S) throughout the experimental seasons (Table 6). These results are in line with study outcome of Epstein and Bloom (2006) who confirmed that chlorophyll content is approximately proportional to leaf nitrogen concentration which then positively correlates with aphid infestation.

During the long rains of 2018 (Table 7), the different plant host species; stinging nettle, coriander and the three common bean varieties of KK8, GLPX92 and Punda differed significantly ($P<0.05$) in their level of total nitrogen concentration. Highest percentage Nitrogen (4.32%) was recorded in 2019 long rains on variety KK8 both in pure stand and intercrop and lowest (2.21%) observed on coriander during the SR 2017 season. Among the three common bean varieties in the long rains of 2018, PUNDA had a total N% of 4.08 being significantly different from that of GLP92 (3.03) and KK8 (2.68). The higher N% possibly was the reason for the higher leaf aphid incidence levels of PUNDA-VE variety (SR-2017, 0.404), (LR-2018, 0.387), (SR-2018, 0.463) and (LR-2019, 0.449) for the entire field trial period compared to all the other negative control treatments of varieties GLP92 and KK8 (Table 1). This positive correlation of total N% and leaf aphid infestation for PUNDA-VE is in agreement with the research findings of Warbrick-Smith et al. (2006) who established that Nitrogen, especially essential amino acids (EAAs), in plant hosts are critical in determining whether or not insect herbivores can establish on hosts successfully. This was further illustrated by Pompon et al. (2011) who documented that amino acid concentration levels in the phloem sap affects aphid probing, settling, survival, larviposition, larval growth, development and wing determination. Similarly, Eubanks, et al. (2003) established that plant nitrogen concentration determines the nutritional quality of plants thus affecting level of insect herbivore infestation. Additionally, Huberty and Denno. (2006), explain that nitrogen concentration of the plant host strongly controls herbivore performance, population dynamics and outbreak frequency upon landing of the insect pest. Similar findings were noted by Wilkinson and Douglas. (2003) who revealed that amino acid composition in phloem varies among different plant species. Total percentage Nitrogen significantly ($P<0.05$) differed with crop stage during the short rain seasons of 2017 and 2018. In both cases Nitrogen percentage in vegetative and maturity stages was higher than that of flowering/podding (Table 8). During vegetative stage of the crop, nutritional status (Nitrogen) was higher probably due to leaf flush (Sandstrom, 2000), because the various organs of the plant are fully developed to effectively uptake nutrients from the soil and carry out effective photosynthesis.This concides with the period of highest aphid infestation which according to Will et al., 2013 influences herbivore performance in terms of fecundity, growth rates, and survivorship. According to Doring (2014), high aphid infestation level at maturity stage could be attributed to the yellow colour resulting from leaf senescence. Sandstrom (2000), explains that during leaf senescence, nitrogen bound in the chloroplasts is degraded and mobilized as soluble nitrogen (amino acids) which is easily available for aphid uptake.

Plant sap pH differed among varieties despite the fact that the plant species were growing within the same environmental conditions (Table 9). According to Masoero and Gugnetto (2018) earlier experimental findings, plant sap pH variation could be partly intrinsic (presumably genetic) since differences are observed among plant species growing in the same soil conditions. Stinging nettle consistently recorded the highest pH (Table 9) and aphid incidence and severity (Tables 1, 2, 3 and 4) in all the seasons. Stinging nettle pH in the four seasons was; SR-2017 (7.723), LR-2018 (8.44), SR-2018 (7.99) and LR-2019 (8.63) all above pH 6.4 thus favouring aphid infestation (Tables 1, 2, 3 and 4). Elmer and Datnoff. (2014) reported that a plant's ideal cellular fluid pH is 6.4, point at which the saturation of cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) other than hydrogen (H^+) is about 88 percent. At 88 percent saturation of these cations, the ionization and activity of these elements generates an electrical frequency of between 7.5 and 32 Hertz, which is indicative of healthy frequency ranges of all living cells. Husson (2013) explained that at pH higher than 6.4 as was the case with stinging nettle (Table 9), saturation of Ca^{2+}, Mg^{2+}, K^+ and Na^+ cations increased to over 88 percent which meant that the frequency from these ions in the cell increased, and consequently favoured aphid infestation. On the contrary, all other species had pH less than 6.4 which was not good medium for heavy aphid infestation for instance coriander with pH of 5.95 in the short rains of 2017 (Table 9) had a negligible aphid leaf incidence of 0.006 (Table 1). According to the research report of Saleh and Al-Shareef (2010), as plant sap pH varies below or above (6.4) there is imbalance of minerals and an increased susceptibility to disease or insect pest attack respectively. In this scenario, insect pests of interst are in the order homoptera which includes aphids which are phloem sap feeders. Awadalla *et al*. (2014) concur with this argument by demonstrating that variation in plant pH affects aphid performance such as growth rates, fecundity, and survivorship.

Conclusion

Pest problems present major constraints to agricultural productivity of the common beans, particularly in the tropics. *Aphis fabae,* Scopoli is ranked as one of the most serious pests of common beans world wide. Due to its wide host range, complex life circle and high reproduction rate, control of this pest using synthetic insecticides, the most common control strategy is not effective. Besides, most farmers in Kisii county rarely control aphids on common beans either due to ignorance or high costs involved in pesticide use. Where pesticides have been used, the application has been indiscriminate, leading to chemical resistance by the target pest and environmental pollution. It is therefofe important to resort to other available aphid management strategies.

In this study, three varieties of common bean, coriander (*Coriandrum sativum*, L.) and stinging nettle (*Urtic*a *dioica*, L.) were intercropped to test their ability and level of effectiveness in the control of *Aphis fabae*. This was compared to aphid infestation levels in positive control plots (chemical pesticide sprayed) and negative controls plots (no chemical pesticide used). Aphid infestation in bean, nettle and coriander intercrop reduced significantly, compared well with sprayed (positive control) plots but differed significantly with infestation in the unsprayed (negative control) plots. It can therefore be deduced that use of companion crops (coriander and stinging nettle) can effectively control aphids and contribute to yield increase without being harmful to human health and the environment in general.

Recommendation

Chemical insecticides have a quick knock down effect on aphids hence quite effective during insect pest outbreaks. However, due to their possible negative effects on beneficial insects, persistence in the environment and human health concerns, alternative control strategies are recommended. Integrated pest managent (IPM) approach in which a combination of all possible insect pest control measures are used, should be embraced. In IPM, all effective, economical, and environmentally sound pest control methods are blended into a single but flexible approach to managing pests. Adoption of this technology will ensure that farmers in Kisii County optimally utilize their small parcels of land by growing these short maturity and pest tolerant common bean varieties at least twice in one year. The intercrops have many other advantages including; crop canopy which smothers weeds and prevents soil erosion and can be used to enrich soil fertility levels. Further study can be conducted to investigate the best intercrop species and pest tolerant common bean varieties, plot design and crop spacing for maximum aphid control and higher common bean yields.

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