

FLEA BEETLE POPULATIONS AND ECONOMIC YIELD OF OKRA AS INFLUENCED BY NITROGEN AND 2, 3-DIHYDRO-2, 2-DIMETHYL BENZOFURAN

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ABSTRACT

Nitrogen fertilisation and carbofuran applications impact plants, yet few studies examine their general impact on plant performance and plant susceptibility to insect pests and diseases when applied together. The performance of okra (*Abelmoschus esculentus* L. Moench) and infestations by flea beetles in relation to nitrogen and carbofuran applications were, therefore, evaluated under a humid tropical environment. Treatments comprised of combinations of four rates of 2, 3-dihydro-2, 2-dimethylbenzofuran or carbofuran (0.0, 0.5, 1.0 and 1.5 kg ha⁻¹) and four levels of N- fertiliser (0, 40, 80 and 120 kg ha⁻¹). The presence of *Podagrica uniformis* was recorded much earlier on the plants than *Nisotra sjostedti*. The population of either flea beetle remained lower throughout the vegetative than the reproductive phase. While N fertilisation resulted in higher insect count than where no N was added, carbofuran at 1.0 kg ha⁻¹ and above significantly (P<0.05) depressed the flea beetle populations up to 5 weeks after planting. Differences in the carbofuran and N interaction had no statistical significance on insect count. All cases of applied carbofuran and nitrogen increased earliness to maturity, plant height, total fruit number, fruit weight, fruit yield and net marginal returns. Higher doses of carbofuran in combination with nitrogen significantly increased earliness to plant maturity, fruit number per plant, fruit yield and net marginal returns. The best fruit yield was attained by combining 1.0 kg ha⁻¹ carbofuran with 80 kg N ha⁻¹, while the best economic return was achieved by combining 0.5 kg ha⁻¹ carbofuran with 80 kg ha⁻¹. Incidence of mosaic disease was suppressed with increasing doses of carbofuran or decreasing doses of nitrogen.

Key Words: *Abelmoschus esculentus*, Carbofuran, *Nisotra sjostedti*, *Podagrica uniformis*

RÉSUMÉ

La fertilisation azotée ainsi que l'application du carbofuran affectent les plantes, mais peu d'études examinent leur impact sur la performance et la susceptibilité des plantes aux pestes et maladies, lorsque les deux sont appliqués ensemble. La performance d'Okra (*Abelmoschus esculentus* L. Moench) et des infestations par des coléoptères en relation avec l'application de l'azote et du carbofuran étaient ainsi évaluées sous un environnement à climat humide tropical. Les traitements comprenaient une combinaison de quatre doses de 2, 3-dihydro-2, 2-diméthylbenzofuran ou carbofuran (0.0, 0.5, 1.0 et 1.5 kg ha⁻¹) et quatre niveaux d'engrais N (0, 40, 80 et 120 kg ha⁻¹). La présence de *Podagrica uniformis* sur les plantes était observée un peu plus tôt que le *Nisotra sjostedti*. La population de coléoptères était restée plus basse dans la phase végétative que dans la phase reproductive. Alors que le nombre d'insectes était plus élevé dans les traitements sous fertilisation azotée que dans le contrôle, la dose de plus ou moins 1.0 kg ha⁻¹ de carbofuran avait significativement (P<0.05) réduit les populations de coléoptères jusqu'à cinq semaines après le semis. Aussi, il n'y avait pas eu de différence significative en terme d'interaction entre le carbofuran et d'azote appliqués. Dans tous les cas, le carbofuran et l'azote avait eu un effet sur la maturation précoce, la hauteur de plants, le nombre total de fruits, le poids de fruits, le rendement en fruits ainsi que sur des bénéfices marginaux nets. La combinaison de doses élevées de carbofuran et d'azote avait affecté significativement la susceptibilité de la plante à la maturation précoce, le nombre de fruits par plante, le rendement en fruits et les bénéfices marginaux nets. Le meilleur rendement en fruit était réalisé par la combinaison de 1.0 kg ha⁻¹ de carbofuran

avec 80 kg N ha⁻¹, alors que la combinaison de 0.5 kg ha⁻¹ de carbofuran avec 80 kg ha⁻¹ d'azote était la meilleure du point de vue de la rentabilité économique. L'incidence de la maladie de mosaïque était contrôlée soit par l'augmentation des doses de carbofuran ou par la diminution des doses d'Azote.

Mots Clés: *Abelmoschus esculentus*, Carbofuran, *Nisotra sjostedti*, *Podagrica uniformis*

INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench) is an important vegetable crop almost consumed worldwide. The tender fruits, leaves and succulent shoots are consumed, either in fresh or dried forms (Arapitsas, 2008). The fruit is a greenish capsule, slightly curved, six-chambered pods of fibrous texture, containing numerous seeds (Lengsfeld *et al.*, 2004). The thick slimy juice of the fruits makes it a relish in the preparation of soup for pounded yam and foofoo. It is also an important source of fibre and thus a multipurpose crop.

Okra consumption among other fruit vegetables were found beneficial in moderating blood pressure, fibrinogen concentration and plasma viscosity in Nigerian hypertensives (Adebawoo *et al.*, 2007)

Problems of okra production in Nigeria are insect pest infestations, disease incidence and poor soil nutrient level. It has become a common sight to find numerous perforations on the leaves of okra usually caused by herbivorous insects, which is almost being accepted as a common feature of the crop (Egwuatu, 1982). Youdeowei (2002) has documented insects of primary importance in the cultivation of okra crop. Egwuatu (1982) noted that *Podagrica uniformis*, Jacoby and *Nisotra sjostedti*, Jacoby (Col.: Chrysomelidae) are the most destructive insect species at Nsukka, Nigeria.

Okra mosaic virus (OMV), which is transmitted by insects belonging to *Podagrica* species, has been reported from Côte d'Ivoire, Kenya, Nigeria and Sierra Leone in Africa (Brunt *et al.*, 1996; Fajinmi and Fajinmi, 2010). The flea beetles and *Syagrus calcaratus* (Fab.) (Col.: Chrysomelidae) have also been implicated in the transmission of OMV in okra (Fajinmi and Fajinmi, 2010). But farmers ignore such diseases because they lack information on their control (Ndunguru and Rajabu, 2002).

In a field trial with other insecticides for the control of okra flea beetle, Egwuatu (1982), found 2,3-dihydro-2, 2-dimethylbenzofuran (carbofuran) as the most effective at 1.5 kg a.i. ha⁻¹ both in terms of yield improvement and insect reduction compared to other insecticides used. Carbofuran and other systemics have also been reported to enhance the growth and yield of treated plants to varying extents (Ceccon *et al.*, 2004; Van Hezewijk *et al.*, 2008).

Several researchers have also recognized nitrogen fertilisation as a booster of crop growth, development and yield in the presence of favourable environmental influences (Groot *et al.*, 2003; Van Hezewijk *et al.*, 2008; Prvulovic *et al.*, 2010; Useche and Shipley, 2010).

Besides its effect on growth, development and yield of crops, application of nitrogen has also been reported to influence the susceptibility of plants to pests and diseases (Youdeowei, 2002; Van Hezewijk *et al.*, 2008). But there is paucity of information on the effect of combined application of N fertilisation and carbofuran treatment on crop development, pest and disease incidence. This may eventually influence their application rates especially when applied together. The objectives of this study were to:

- (i) evaluate the phenological relationship between okra growth stages and the incidence of okra flea beetles (*P. uniformis* and *N. sjostedti*);
- (ii) determine the minimum effective rates of carbofuran and/or nitrogen application for the control of the flea beetles of okra; and
- (iii) assess the influence of carbofuran and/or N-fertilisation on the growth and yield of okra.

MATERIALS AND METHODS

The study was carried out at the Teaching and Research farm of Faculty of Agriculture, University of Nigeria, Nsukka (Lat. 06° 52'N, Long. 07° 24'E; elevation 447.26 m above mean sea level) between 2005 and 2006 cropping seasons. Jungerius (1964) and Enwezor *et al.* (1989) classified the soil of the ecozone as Typic Ultisol. From long term meteorological data, the annual rainfall was normally bimodal with peaks in July and September.

Treatments involve factorial combinations of four rates of Furadan 3G® (a.i.= carbofuran) (0.0, 0.5, 1.0 and 1.5 kg a. i. ha⁻¹) and four levels of nitrogen (0, 40, 80 and 120 kg ha⁻¹) laid out in randomised complete block design, with three replications. The site was mowed, ploughed and harrowed to a fine tilth. Each of the three blocks was divided into 16 plots, each measuring 2.7 m x 1.8 m with 0.5 m pathways between the plots and 1.0 m between blocks.

Okra seeds of 'cv' "Awgu Early", obtained from Ministry of Agriculture, Market Garden, Enugu were dressed with Apron plus® (metalaxyl + carboxin + furathiocarb) at the rate of 10 g 2 kg⁻¹ of seeds to give the seedlings the initial prophylactic treatment. Planting was done on raised beds, two seeds being drilled per hole at about 3 cm depth. The seedlings were later thinned down to one plant per stand after the first two leaves had properly emerged. Spacing was at 60 cm between rows and 45 cm within the row giving a population of 37,037 plants per hectare.

Blanket applications of single super phosphate and muriate of potash were made at the rates of 30 kg P ha⁻¹ and 90 kg K ha⁻¹ to each of the plots at the 3-leaf stage of the plants, 15 days after planting (DAP). Furadan (carbofuran) was weighed out at the appropriate rates and placed in the drilling holes of the seeds at planting. Nitrogen as urea, was applied at 3-leaf stage (15 DAP) using various rates and to appropriate plots.

The insect counts were based on the four inner plants per plot. Plants showing mosaic symptoms expressed as vein clearing, vein banding, mottled and mosaic patterns were

counted from 8 weeks after planting. This was expressed as the percentage of the four inner plants per plot showing this symptom. Observations on yield and yield components were based on days to 50% flowering, plant height at 50 DAP, fruit number, weight per fruit and fruit yield per hectare.

The net profit after deducting cost of insecticide, fertiliser and labour inputs was computed and recorded as net marginal returns.

Data collected were subjected to analysis of variance according to the procedure outlined by Steel and Torrie (1980). Insect count and per cent disease incidence were subjected to square root and arc sin transformations, respectively, before analysis of variance were carried out. Detection of differences among treatment means was carried out using the Least significant difference (LSD) procedure.

RESULTS

The preponderant insect pests of major importance observed were *Podagrica uniformis*, Jacoby and *Nisotra sjostedti*, Jacoby (Coleoptera; Chrysomelidae). Arrival of the species on okra plant started 3 WAP in plots where carbofuran was not applied, and where the highest N rate (120 kg ha⁻¹) was applied (Table 1). Other plots did not show infestation until 5 WAP. At 5 WAP, carbofuran at 1.0 or 1.5 rates depressed insect pest infestation significantly (P<0.05).

Nitrogen application resulted in higher insect population than where no N was applied. Interaction of the two treatments did not produce significant (P>0.05) effects. At 7 or 9 WAP, insect pest infestation had become more appreciable than at the earlier stages of plant development. At this stage, differences in the pest population with N fertilisation or with carbofuran treatment were not significant. However, there was an evidence of higher pest population with increasing N- treatment, while especially 1.5 kg ha⁻¹ of carbofuran appeared to depress the pest population.

The variations in population of the two major insect pest *Podagria uniformis* and *Nisotra sjostedti* at different stages of okra plant development are summarised in Figure 1. *Nisotra sjostedti* infestation on okra plants occurred one

TABLE 1. Flea beetle density as influenced by carbofuran and nitrogen at various stages of growth in Nigeria

Weeks after planting	Carbofuran rates (kg ha ⁻¹)	Nitrogen levels (kg ha ⁻¹)				Mean
		0	40	80	120	
3	0.0	0.0	0.0	0.0	7.0	1.8
	0.5	0.0	0.0	0.0	0.0	0.0
	1.0	0.0	0.0	0.0	0.0	0.0
	1.5	0.0	0.0	0.0	0.0	0.0
5	0.0	3.3	3.6	7.2	4.3	4.6
	0.5	3.4	3.5	7.0	3.7	4.4
	1.0	0.0	1.1	0.0	0.2	0.3
	1.5	0.5	0.7	0.0	0.7	0.5
7	0.0	12.8	25.1	16.9	18.0	18.2
	0.5	10.0	36.2	20.9	23.2	22.6
	1.0	13.0	17.2	17.9	18.0	16.8
	1.5	8.1	16.7	8.1	15.9	12.2
9	0.0	9.4	57.3	33.3	40.2	35.1
	0.5	41.8	78.7	62.9	29.6	53.3
	1.0	21.0	26.1	27.5	98.7	43.3
	1.5	34.3	33.7	18.7	29.1	29.0

Weeks after planting

3 5 7 9

LSD_{0.05} for comparing 2 carbofuran or nitrogen means = NA 0.7 NS NSLSD_{0.05} for comparing 2 carbofuran x nitrogen means = NA NS NS NS

NA = Not analysed

week later than *P. uniformis*. Except for a lower value at 8 WAP, the population of *N. sjostedti* was always more abundant than *P. uniformis*.

Generally, the flea beetle count was relatively low at the vegetative stage of okra, but increased progressively through the flower, fruit set and fruit harvest stages. It peaked at the senescence stage.

The number of days to 50% flowering was progressively reduced with increasing rates of carbofuran application (Table 2). All cases where carbofuran was applied had significantly less days to flowering than where no carbofuran was applied. Where 1.5 kg a.i. of carbofuran was applied attained 50% flowering in significantly ($P < 0.05$) less okra days than where only 0.5 a.i. was applied.

Application of fertiliser N progressively depressed the number of days taken to attain 50% flowering. Combinations of 80 to 120 kg N

ha⁻¹ with 1.0 - 1.5 kg a.i. of carbofuran generally reduced the number of days to flowering than combinations of low rates of carbofuran and N fertiliser.

All cases of applied carbofuran did not differ from each other in their effects on plant height, but produced significantly ($P > 0.05$) taller plants than where no carbofuran was applied. Nitrogen generally produced significantly ($P < 0.05$) taller plants than the control. Differences in plant height among treatment combinations were not significant. However, there was an evident trend of taller plants with combinations of higher rates of carbofuran and nitrogen than their lower rates.

The incidence of mosaic symptoms were progressively depressed by application of carbofuran, while application of nitrogen significantly increased the incidence of the disease. The disease incidence was always more

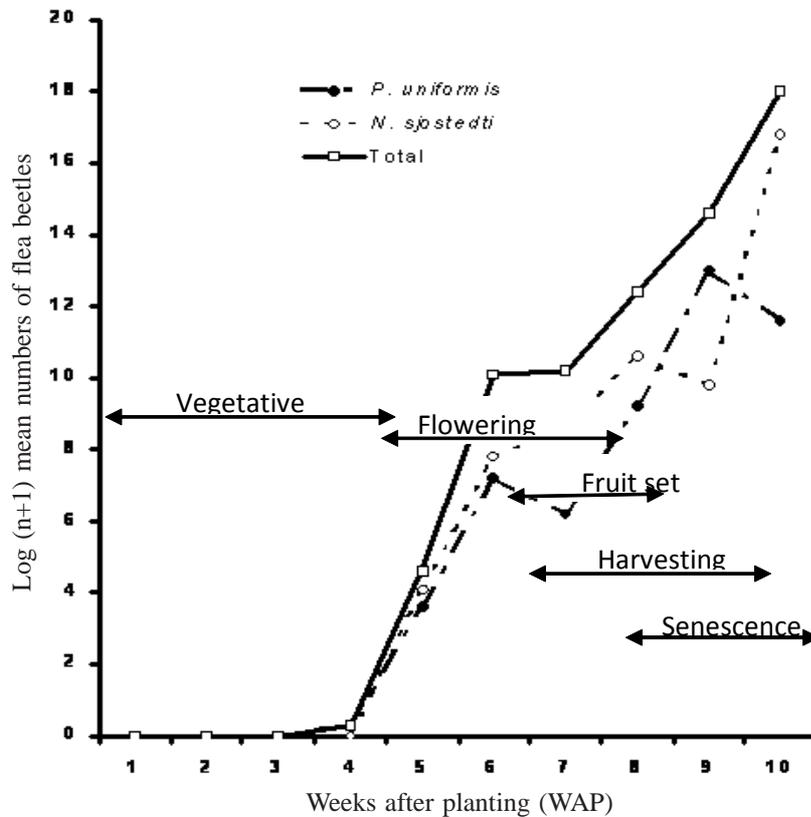


Figure 1. Variation in the density of *Podagrica uniformis* and *Nisotra sjostedti* with advancing age of Okra 'cv' Awgu early.

prevalent where no carbofuran or the rate of 0.5 kg a.i. was applied, especially where high rates of nitrogen were used. The combination of 80 N ha⁻¹ and 1.0 or 1.5 kg a.i. of carbofuran showed a better control of the okra mosaic disease.

Application of higher rates of carbofuran produced more ($P < 0.05$) fruits than where no carbofuran or 0.5 rate was applied (Table 3). Nitrogen treated plants also produced more fruits than untreated plants. Combinations of 80–120 kg N ha⁻¹ with 1.5 kg a.i. ha⁻¹ carbofuran produced the highest fruit numbers. Application of carbofuran progressively increased the fruit weight of okra per fruit. Application of 1.5 kg a.i. ha⁻¹ showed no difference with application of 1.0 kg a.i. ha⁻¹. However, 80 kg N ha⁻¹ significantly increased fruit weight over the N control or at 40 kg N ha⁻¹. Weight per fruit appeared highest with a combination of 1.5 kg a. i. ha⁻¹ of carbofuran and 80 kg N ha⁻¹. The effects of carbofuran and N application on fruit (kg ha⁻¹) followed similar

trends as their effects on weight per fruit. Fruit yield and economic return improvements did not go beyond the rates of 1.0 kg a.i. of carbofuran or 80 kg N ha⁻¹. Combined applications of 0.5–1.5 kg a.i. of carbofuran and 80 kg N ha⁻¹ appeared to produce the best yield and economic return.

DISCUSSION

The greater preponderance of flea beetles during the reproductive phase of the plant compared with the vegetative phase could be attributed to the increasing abundance of food sources. Such food sources on okra plant may include flower buds, flowers and pods that were more in abundance at the reproductive stage of the plant compared with the vegetative phase. This result supports the thesis of greater insect aggregations with more sources of food supply (Egwuatu and Taylor, 1976). The choice of flower buds,

TABLE 2. Effect of carbofuran and nitrogen on days to 50% flowering, plant height at 50 days after planting and incidence of okra mosaic disease in Nigeria

Parameter	Carbofuran rates (kg ha ⁻¹)	Nitrogen levels (kg ha ⁻¹)				Mean
		0	40	80	120	
Days to 50% flowering	0.0	62.3	55.3	50.0	45.7	53.3
	0.5	58.3	53.3	42.0	41.0	48.7
	1.0	58.3	51.0	41.0	41.0	47.8
	1.5	55.0	51.0	40.0	40.3	46.6
Plant height (cm)	0.0	23.5	31.0	30.0	32.1	29.1
	0.5	28.8	43.3	31.7	31.3	35.0
	1.0	29.3	33.3	34.9	42.4	34.9
	1.5	23.3	34.3	36.6	40.1	34.8
Okra mosaic disease incidence	0.0	13.3	23.3	48.3	96.7	45.4
	0.5	13.3	20.0	15.0	66.7	28.8
	1.0	3.3	3.3	10.0	16.7	8.3
	1.5	3.3	3.3	0.0	13.3	5.0

	Days to 50% flowering	Plant height	Mosaic disease incidence
LSD _{0.05} for carbofuran or nitrogen means	1.6	4.3	0.5
LSD _{0.05} for carbofuran x nitrogen means	3.1	NS	1.1

flowers, succulent pods as well as matured pods for food by the flea beetles has been documented by Schippers (2000).

The relative abundance of *Nisotra sjostedti* over *Podagrica uniformis* in all the sampling period suggests a stronger preference for okra plant parts by *N. sjostedti* than *P. uniformis*. This may have accounted for the eventual relative displacement of the latter by the former. This displacement might be due to interspecific competition between the two species. The relative abundance of these species, however, may be an important response in elucidating their feeding behaviours as well as their biology.

The differential efficacies of carbofuran rates on flea beetle control up to 5 weeks after planting (WAP) was attributed to the powerful systemic mode of action of the soil applied insecticide. This action appeared to wane down after 5 WAP and, thereafter became ineffective. On tropical soils, the half-life of carbofuran ranges between 30 and 60 days (Anon, 1972). With carbofuran, Egwuatu (1982) recommended that a single dose at planting holes would be most meaningful. Such single dose application is expected to obviate possible residue problems during the fruiting

periods that may arise as a result of repeated applications.

Promotion of plant growth as recorded in this study with carbofuran or nitrogen treatment could account for the significant yield improvement achieved by the two treatments. According to Ceccon *et al.* (2004) and Van Hezewijk *et al.* (2004), carbofuran and other systemics are known to promote growth and enhance the yield of the affected crops. Similarly, Groot *et al.* (2003); Van Hezewijk *et al.* (2008) and Prvulovic *et al.* (2010), recorded that nitrogen fertilisation promotes growth and yield of some crops at some levels of application. Taller plants could mean more internodes and nodes for possible pod attachments and, therefore, better chances for more fruit yield. Although there was a progressive trend of heavier fruits with increasing combined doses of carbofuran and nitrogen, significant differences were only detected among these traits for both.

The non-production of significant desired synergistic effect on crop growth and fruit weight by the combined applications of nitrogen and carbofuran might be attributed to the

TABLE 3. Effect of carbofuran and N fertiliser applications on okra yield components and net margin

Parameter	Carbofuran rates (kg ha ⁻¹)	Nitrogen levels (kg ha ⁻¹)				Mean
		0	40	80	120	
Fruit number per plant	0.0	9.5	11.9	9.7	9.3	10.1
	0.5	11.9	11.3	12.5	7.3	10.8
	1.0	10.8	17.1	14.7	12.3	13.7
	1.5	11.3	16.8	18.2	20.1	16.6
Weight per fruit (g)	0.0	22.2	24.7	34.6	29.1	27.7
	0.5	30.5	27.5	34.5	35.0	31.9
	1.0	31.5	35.9	42.6	43.5	38.4
	1.5	35.8	37.3	44.9	42.1	40.0
Total fruit yield (t ha ⁻¹)	0.0	8.9	9.9	13.6	11.7	11.0
	0.5	12.6	11.0	13.8	14.0	12.9
	1.0	12.6	14.4	17.1	17.5	15.4
	1.5	14.3	15.3	18.0	16.1	15.9
Net margin (₦ ha ⁻¹)*	0.0	709120.0	789105	1103223	924541.1	881497.2
	0.5	957837	860755	1081219	1095818	998907.1
	1.0	973497	1112682	1332719.6	1351478	1192594
	1.5	1095173.3	1170038	1382289.6	1287981.1	1233871

	Fruit No.	Fruit wt	Total yield	Net margin
LSD _{0.05} for comparing 2 carbofuran or 2 nitrogen means	2.5	6.1	2.4	194138.2
LSD _{0.05} for comparing 2 carbofuran x nitrogen means	5.0	-	4.0	388276.4
* ₦120 = \$1 (USD)				

uncomplimentary effect of the treatment combinations. The possession of different metabolites and/or mechanisms by the two treatments possibly affords them different metabolic pathways especially when applied together. The different pathways may possibly result in the no-significant plant growth and fruit weight improvement effect that resulted when both were applied together. The growth metabolites of carbofuran are carbofuran phenol and 3-hydroxyl carbofuran (Trevisan *et al.*, 2004), while the growth mechanism in nitrogen is by protein synthesis and carbohydrate utilisation (Andrew *et al.*, 2007).

The significant reduction in the mosaic symptom expression on the carbofuran treated plots, even with the in-undated populations of the flea beetles recorded after 5 WAP, suggests that control of disease vectors at the early plant growth produces a better yield and suppression of disease incidence than control in the later

stages of crop growth. Marchie (1993) reported that okra mosaic virus OKMv infection at six or more weeks after planting did not significantly affect okra yield. Fajinmi and Fajinmi (2010), also reported that inoculation of okra plants with OKMv 14 and 21 days after emergence (DAE) significantly reduced the weight of fruits per plant compared with those inoculated 28 DAP or non-inoculated control. They, however, concluded that flea beetles have been seriously implicated in the transmission of okra mosaic virus to okra plants in the field.

The progressive increase in the incidence of insect pests and mosaic disease expression with increased N fertilisation was attributed to the increased hydration and succulence of the plant tissues. Draycott and Christenson (2003) reported that excessive application of N increases tissue hydration and succulence and could therefore predispose such organs to more pest and disease attack.

Although the combined application of 1.5 kg ha⁻¹ carbofuran and 80 kg N ha⁻¹ gave the highest fruit yield of 18 t ha⁻¹, the use of 0.5 kg a.i. ha⁻¹ carbofuran and/or 80 kg N ha⁻¹ resulted in the highest marginal economic returns. Further application of carbofuran and/or nitrogen were uneconomical. Single application of 1.5 kg ha⁻¹ carbofuran was considered effective by Egwuatu (1982). The 1.5 rate was found significantly higher than the 1.0 rate or even the combination of 0.5 rate with 80 kg N ha⁻¹ in this study. The reduction in this minimum effective rate was attributed to the marginal cost implication as well as the interactive effects of nitrogen. Depending on concentration, nitrogen fertilisers could predispose a plant to disease or pest attack (Van Hezewijk *et al.*, 2008). Other agrobotanical traits assessed also attained statistical significance with incremental doses of carbofuran and/or nitrogen probably due to their therapeutic effects on the pests and diseases of the crop.

CONCLUSION

The phenological relationship between okra growth and the incidence of flea beetles (*Podagrica uniformis*, Jacoby, and *Nisotra sjostedti*, Jacoby) are amply evident. *Podagrica uniformis* appears earlier than *N. sjostedti*, and their population is generally lower during the vegetative than during the reproductive stages of okra. *Podagrica uniformis* occurs earlier on the plants and its population also depressed earlier at 9 weeks after planting. *Nisotra sjostedti* occurred later and the population increased rather dramatically, until sampling was discontinued. Carbofuran applied at 1.0 kg ha⁻¹ and above gives effective control of the flea beetles up to 5 WAP. Application of 80 kg N ha⁻¹ and above favoured infestation after 5 WAP. There is no carbofuran X nitrogen interaction effect on flea beetle counts. Applications of carbofuran and/or nitrogen, on the other hand, increases fruit number, fruit weight, fruit yield, net marginal returns and earliness to maturity. Applications of 0.5 kg ha⁻¹ carbofuran and 80 kg N ha⁻¹ gives the best fruit yield harvest and net marginal return. The incidence of mosaic disease symptom is suppressed with increasing doses of carbofuran.

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