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Full Length Research Article

CORRELATION ANALYSIS BETWEEN DAMAGE PARAMETERS AND COWPEA YIELD DUE TO POST-FLOWERING INSECT PEST IN KATSINA, SADANO-SAHELIAN ECOLOGY, NIGERIA

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ABSTRACT

Damage indices and yield potential of cowpea were compared in a field trial consisting of intra-row spacings, sowing dates, and pesticides as a combination of Integrated Pest Management (IPM) on a complex of pod-sucking bugs (CPSBs) and cowpea pod-borer populations. The trial was carried out during the rainy seasons of 2015 and 2016 in Katsina, with a sudano-sahelian ecology. The trial aims to compare the relationship between yield and CPSB damage indices. The experiment was laid out using a split-split plot design with intra-row spacings (SP_1-75 × 20 cm, SP_2-75 × 30 cm, and SP_3-75 × 40 cm) allocated to the main plot, sowing dates (SD1-2 July; SD2-23 July, and SD3-13 Aug.) to the sub-plot, and the sub-sub-plots were allocated to pesticides (neem kernel seed extract (NKE), *Maruca vitrata* Multi-Nucleopolyhedrosis (MaviMNPV) viral suspension, synthetic insecticide (Cyper diforce), and a control. The treatments were randomized and replicated three times. Data were measured on damage parameters caused by a complex of pod-sucking bugs (CPSBs) and legume pod borer, *Maruca vitrata*. The data were correlated using the Pearson Correlation Coefficient for a Two-tailed test with df = (N-2) at $^*P \leq 0.05$ (r = 0.250) and $^{**}P \leq 0.01$ (r = 0.325) using SAS software. The combined interaction results indicated that a significant and positive correlation (r>0) exists between the post-spray population of M. vitrata and the post-spray flower damage 10 WAS, respectively (0.766**). Similarly, percentage (%) *M. vitrata* population in cowpea pods was positively and highly related to % cowpea damage by *M. vitrata* 10 WAS, respectively (0.751**). Yield was, however, negatively (r<0) and weakly related to percentage cowpea damage by CPSBs at harvest (-0.420**) and % grain damage by *M. vitrata* in 300 g (-0.265*). It is therefore recommended that, for successful, high-yield cowpea in the study area and similar ecologies, synchronized sowing and the application of control measures should be initiated early, before the critical cowpea reproductive phase, to reduce infestation and improve yield.

Keywords: Correlation analysis, damage parameters, cowpea yield, post-flowering insects, Sadano-sahelian ecology, and Nigeria.

INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp.) is a widely cultivated grain legume across sub-Saharan Africa, Asia, and parts of Latin America. It is a dicotyledonous plant and is one of the most important food legumes grown in tropical and subtropical regions, where it provides a major source of dietary protein, income generation, and livestock feed (Ajeigbe *et al.*, 2012; Ahmed *et al.*, 2009; Oyewale & Bamaiyi, 2013). Nigeria and Niger account for 66% of world cowpea production (Maina *et al.*, 2016). In Africa, cowpea is predominantly produced by smallholder farmers as a subsistence crop and plays a vital role in food security. According to Ajeigbe *et al.* (2012) and International Institute of Tropical Agriculture (IITA, 2009), cowpea cultivation is concentrated mainly in the savanna zones of Africa, Asia, and South America, The African Agricultural Technology Foundation (AATF, 2014) identified cowpea as the most important grain legume in the dry savannas of tropical Africa, occupying over 12.8 million hectares, with nearly 200 million Africans depending on it for food. Despite its socioeconomic importance, cowpea productivity is severely limited by numerous biotic and abiotic constraints.

Insect pests remain a major production bottleneck, particularly those that infest the crop during the post-flowering stage. Jackai & Daoust (1986) reported that cowpea is a crop well adapted to marginal environments, yet its yield remains far below its genetic potential due largely to insect pest pressure. Post-flowering pests attack flowers, pods, and developing seeds, resulting in considerable yield reduction and deterioration of grain quality (Karungi *et al.*, 2000). Under severe infestation and without control measures, yield losses can exceed 70–80%; in extreme cases, losses of up to 90% have been reported (Soratur et al., 2017; IITA, 2009; Lambot, 2002).

The most damaging of all insect pests are those attacking at the flowering stage (including the leaves). Such as flower bud thrip, *Megalurothrips sjostedti* Trybom [Thysanoptera: Thripidae]; flower-feeding blister beetles, *Mylabris* spp. [Coleoptera: Curculionidae]; cowpea pod-borer, *Maruca vitrata* (Fab.) [Lepidoptera: Crambidae]; leafhoppers, *Empoasca sp* [Homoptera: Cicadelidae]; common whitefly, *Bemisia tabaci* Genn. [Homoptera: Aleyrodidae] reported by Allen *et al.* (1996) and Oyewale and Bamaiyi (2013). Post-flowering insect pests. A major constraint for cowpea grain production was the insects that attack cowpea at the podding and seeding stages. Such insect pests include: pod-sucking bug complexes, which comprise the spiny brown bug, *Clavigralla tomentosicollis* Stål [Hemiptera: Coroeidae], and the giant coroeid bug, *Anoplocnemis curvipes* (F.) [Hemiptera: Coroeidae]; cowpea aphids, *Aphis craccivora* Koch [Hemiptera: Aphididae]; the green stink bug, *Nezara viridula* Linnaeus [Hemiptera: Pentatomidae], and riptortus, *Riptortus dentipes* [Hemiptera: Coroeidae] as reported by Allen *et al.* (1996). Others were the three-spot shield bug, *Aspagia armigera* L., [Hemiptera: Pentatomidae]; Aphids, *Aphis craccivora* Koch [Hemiptera: Aphididae]; jassids, sucking bugs, cowpea pod-borer, *Maruca vitrata* (Fab.) [Lepidoptera: Crambidae] were considered as key pests of cowpea according to Soratur *et al.* (2017).

These insects primarily damage the plant by attacking its most important reproductive part, the flower. Notably, Muhammad *et al.* (2019) observed more serious damage on cowpea flowers by *M. vitrata* 8-10 WAS in untreated cowpea plots. Similarly, flower bud thrips infest and live within flowers causing damage characterized by flower malformation, distortion and discolouration (Allen *et al.*, 1996) thereby rendering pollen grains useless. Activities of pod-sucking bugs were regarded as the most economically important pod pests of cowpea in Africa through sap extraction from developing pods and seeds. Both nymphs and adults penetrate pod walls to feed on developing seeds, resulting in shrivelled grains, pod discoloration, reduced seed weight, and poor germination (Prasad *et al.*, 2021). Additionally, feeding damage facilitates the entry of secondary pathogens, further compromising grain quality (Wudil *et al.*, 2013)—severe infestations significantly lower marketable yield quality and seed viability (Karungi *et al.*, 2000).

Post-flowering insect pests are responsible for the greatest proportion of yield losses in cowpea production systems (Ansar *et al.,* 2024). Evidence shows that combined infestations of *M. vitrata* and pod-sucking bugs can cause yield reductions exceeding 80% in the absence of control measures (Oerke, 2006). Similarly, Maina *et al.* (2016) suggested that attacks or severe damage to flowers and pods 21 days after anthesis could affect the grain yield of cowpea in Maiduguri, Borno State, Nigeria. Complete crop failure may occur, especially when management strategies are not implemented, as observed by Oyewale and Bamaiyi (2013). Beyond quantitative yield losses, these pests adversely affect seed quality, germination capacity, and market value, thereby disrupting food and seed systems. Yield losses attributed to *M. vitrata* alone range from 20% to more than 80%, depending on varietal resistance, planting time, and pest management practices (Karungi *et al.*, 2000). In severe outbreaks, total crop failure has been observed, particularly in untreated fields. These losses disproportionately affect smallholder farmers, who often lack access to effective pest-control technologies, thereby discouraging cowpea cultivation and limiting the adoption of improved varieties. The research was conceived to examine the relationships between the types of damage inflicted on cowpea and yield in the study area.

MATERIALS AND METHODS

Study Area

A field experiment was conducted during the 2015 and 2016 rainy seasons at the Teaching and Research Farm of the College of Agriculture, Hassan Usman Katsina Polytechnic. The site lies between latitudes 11°07'49" and 13°22'57" N and longitudes 06°52'03" and 09°02'40" E, at an altitude of 619 m above sea level, within the Sudan savanna ecological zone (Ibrahim & Sani, 2012). The area experiences a unimodal rainfall pattern averaging about 742 mm annually, commencing in May/June and ending in September/October, with peak rainfall occurring in August and September. The climate is hot and semi-arid, with mean temperatures ranging from 33.2 to 42.2°C and an average relative humidity of about 60% at 07:00 h. The soil type is predominantly sandy loam (MOANR, 2013).

Sources and Preparation of Pesticides

Neem kernel seed extract (NKE) was prepared from mature neem seeds collected after rainfall from neem forest reserves around Katsina. The seeds were depulped, washed, shade-dried, cracked, and the kernels ground into powder using an electric blender. A quantity of 5 kg ha^{-1} of the powder, together with 2 kg ha^{-1} of bar soap as an emulsifier, was wrapped in clean cloth and soaked overnight in water (Muhammad *et al.*, 2017, 2018, 2019). The mixture was thoroughly stirred and squeezed to obtain a milky suspension following the method described by Oparaeke *et al.* (2005a) and Oparaeke (2006). Liquid gum arabic was added at a rate of 2.7 kg in 6.75 L water ha^{-1} (Kwaifa *et al.*, 2012). The *M. vitrata* Multi-Nucleopolyhedrovirus (MaviMNPV) suspension was obtained from IITA, Cotonou, Benin Republic, and applied following the protocol described by Sokame *et al.* (2015). The suspension was diluted to a concentration of 7.57×10^{11} and applied at 106 ml per hectare in 115 L of water. The synthetic insecticide Cyper diforce®, a class II insecticide containing cypermethrin (30 g L^{-1}) and dimethoate (250 g L^{-1}), was applied at 1.5 L ha^{-1} using a CP-3 knapsack sprayer fitted with a hollow cone nozzle (Muhammad *et al.*, 2018, 2019).

Treatments and Experimental Design

The experiment comprised three intra-row spacings, three sowing dates, three pesticide treatments (two biopesticides, NKE and MaviMNPV, and one synthetic insecticide), and an untreated control. A split–split plot design was employed with intra-row spacing as the main plot factor: 75 × 20 cm (SP_1), 75 × 30 cm (SP_2), commonly used by farmers, and 75 × 40 cm (SP_3). Sowing dates (2 July, 23 July, and 13 Aug.) for SD1, SD2, and SD3, respectively, constituted the sub-plot factor, while pesticide treatments: neem kernel seed extract (NKE- P_1), *Maruca vitrata* Multi-Nucleopolyhedrosis (MaviMNPV) viral suspension (MaviMNPV-P_2), insecticide -Cyper diforce® (P_3), and control (P_0) were assigned to sub-sub-plots. Treatments were randomized and replicated three times. Each plot measured 6 m × 4.5 m (27 m²) and consisted of six ridges spaced 0.75 m apart. The two central rows formed the net plot, with adjacent rows for sampling and border rows for buffering (Kwaifa *et al.*, 2012). The experiment was repeated in 2016 using the same layout.

Agronomic Practices

The field was plowed, harrowed, and ridged mechanically using a tractor. The cowpea variety SAMPEA 7 was used. Seeds were treated prior to planting with Allstar® 40 SD (20% metalaxyl and 20% imidacloprid) at a rate of one sachet per 4 kg of seed (Oparaeke *et al.*, 2005a). Planting was conducted at three-week intervals, with three seeds sown per hole, then thinned to two plants per stand. Single superphosphate fertilizer was applied at 25 kg ha^{-1} immediately after sowing. Mancozeb (80%) was applied at 1.782 kg ha^{-1} to control disease. Weeding was carried out at 3 and 6 weeks after sowing, and gaps were filled three weeks after emergence (Ogah, 2013; Muhammad *et al.*, 2018, 2019). Pesticide applications commenced at 7 weeks after sowing, coinciding with the flowering stage of the crop. Extracts and synthetic insecticides were applied using CP-3 knapsack sprayers, while the viral suspension was applied using a hand-operated sprayer. Spraying was carried out between 06:00 and 07:00 h once weekly for four consecutive weeks (Oparaeke *et al.*, 2005b).

Data Collection and Analysis

Damage indices were collected on total cowpea yield (kg ha^{-1}), post spray *M. vitrata* populations in flowers at 10 WAS, post spray flower damage by *M. vitrata* at 10 WAS, percentage (%) cowpea pod damage by *M. vitrata* at 10 WAS, percentage (%) *M. vitrata* population in cowpea pods sampled 10 WAS, 6 percentage (%) dried cowpea pod damage by *M. vitrata* at harvest, percentage (%) cowpea pod damaged by CPSB at harvest, percentage (%) grain damaged by *M. vitrata* in 300 g, percentage (%) grain damaged by CPSB in 300 g, post spray populations of CPSB 10 WAS and 100 cowpea grain weight (g).

The collected data were subjected to analysis of variance (ANOVA). Treatment means were separated using the least significant difference (LSD) at a 5% probability level with SAS statistical software (SAS, 2000). Data containing zero values were square-root transformed (√n + 0.5) prior to analysis to stabilize variance (Muhammad *et al*., 2018, 2019). Pearson Correlation Coefficient for a Two-tailed test at df - (N-2) at * *P*≤ 0.05 (r = - 0.250) and at **P≤0.01 (r = - 0.325) were used.

RESULTS

Correlation matrices among cowpea damage parameters due to post-flowering insect pests on cowpea yield

The results of the correlation analysis of cowpea damage characteristics during the 2015 and 2016 cropping seasons and the combined results are presented in Table 1-3. The results in Katsina showed that post-spray *M. vitrata* populations in flowers were highly significant (*P*≤ *.01*) and positively and strongly correlated with post-spray flower damage by M. vitrata in flowers at 10 WAS (0.873**, 0.719**, and 0.766**). Similar results were obtained for the percentage of cowpea pods damaged by M. vitrata at 10 WAS (0.626**, 0.516**, and 0.286**). Percentage cowpea pod damaged by *M. vitrata* 10 WAS was also significantly and positively correlated with percentage *M. vitrata* populations in cowpea pods sampled 10 WAS (0.592**, 0.636**, and 0.751**). Weakly and positive correlation was observed by percentage cowpea grain damaged by CPSB in 300 g with post spray *M. vitrata* population in flowers at 10 WAS (0.646**, 0.452** and 0.406**), post spray flower damaged by *M. vitrata* at 10 WAS (0.631**, 0.421** and 0.487**), percentage in cowpea pod damaged by *M. vitrata* at 10 WAS (0.647**, 0.306** and 0.371**), percentage grain damaged by *M. vitrata* in 300 g (0.340**, 0.403** and 0.304**). Similarly, the relationship between total grain yield and cowpea pod damaged by CPSB at harvest was observed to be highly significant but negatively correlated (-0.420*) as well as with percentage cowpea pod damaged by *M. vitrata* at 10 WAS (-0.385**). One hundred cowpea grain weight was also highly and negatively correlated with percentage grain damaged by *M. vitrata* in 300 g (-0.436**) and with percentage grain damaged by CPSB in 300 g (-0.436**). Similarly, a strong and highly significant but negative weak correlation was observed between 100 cowpea grain seed weight and percentage cowpea damaged by M. vitrata in 300 g (-0.491**, -0.542**, and -0.436**) during the 2015 and 2016 cropping seasons and the combined.

Table 1: Correlation Results among Damage Parameters during 2015 Cropping Season

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	1.000										
2	0.092^{NS}	1.000									
3	-0.010^{NS}	0.873**	1.000								
4	-0.082^{NS}	0.626**	0.706**	1.000							
5	-0.051^{NS}	0.505**	0.511**	0.592**	1.000						
6	0.344**	-0.020^{NS}	0.023^{NS}	-0.020^{NS}	0.145^{NS}	1.000					
7	0.193^{NS}	-0.014^{NS}	-0.341**	-0.426**	-0.248^{NS}	0.129NS	1.000				
8	0.092^{NS}	0.185^{NS}	0.219^{NS}	0.120^{NS}	0.176^{NS}	0.443**	-0.044^{NS}	1.000			
9	0.360**	0.646**	0.631**	0.647**	0.513**	0.161^{NS}	-0.310*	0.340**	1.000		
10	0.136^{NS}	0.127^{NS}	0.259*	0.159^{NS}	0.251*	0.134^{NS}	-0.011^{NS}	0.223^{NS}	0.125^{NS}	1.000	
11	0.261*	-0.252*	-0.242^{NS}	-0.261*	-0.134^{NS}	-0.231^{NS}	-0.365**	-0.491**	-0.563**	-0.211^{NS}	1.000

Key: 1 - Yield (kg ha^{-1}), 2 - Post spray *M. vitrata* populations in flowers at 10 WAS, 3 - Post spray flower damage by *M. vitrata* at 10 WAS, 4 - % cowpea pod damage by *M. vitrata* at 10 WAS, 5 - % *M. vitrata* populations in cowpea pods sampled 10 WAS, 6 - % dried cowpea pod damage by *M. vitrata* at harvest, 7 - % cowpea pod damaged by CPSB at harvest, 8 - % grain damaged by *M. vitrata* in 300 g, 9 - % grain damaged by CPSB in 300 g, 10. Post spray populations of CPSB 10 WAS, 11- 100 cowpea grain weight (g), Pearson Correlation Coefficient for a Two-tailed test at df - (N-2) at * *P*≤ 0.05 (r - 0.250) and at ***P*≤0.01 (r - 0.325).

Table 2: Correlation Results among Damage Parameters during 2016 Cropping Season

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	1.000										
2	0.334**	1.000									
3	0.343**	0.719**	1.000								
4	0.330**	0.516**	0.574**	1.000							
5	-0.309*	0.394**	0.445**	0.636**	1.000						
6	-0.117^{NS}	-0.033^{NS}	-0.019^{NS}	0.110^{NS}	0.221^{NS}	1.000					
7	-0.399**	-0.154^{NS}	-0.173^{NS}	0.016^{NS}	0.184^{NS}	0.841**	1.000				
8	0.330**	0.299*	0.394**	0.389**	0.237^{NS}	0.175^{NS}	0.128^{NS}	1.000			
9	0.191^{NS}	0.452**	0.421**	0.306*	0.264*	-0.048^{NS}	-0.137^{NS}	0.403**	1.000		
10	0.321*	0.410**	0.524**	0.391**	0.112^{NS}	0.133^{NS}	0.004^{NS}	0.427**	0.210^{NS}	1.000	
11	0.316*	-0.276*	-0.239^{NS}	-0.285*	-0.154^{NS}	-0.247^{NS}	-0.476**	-0.542**	0.628**	-0.197^{NS}	1.000

Key: 1 - Yield (kg ha^{-1}), 2 - Post spray *M. vitrata* populations in flowers at 10 WAS, 3 - Post spray flower damage by *M. vitrata* at 10 WAS, 4 - % cowpea pod damage by *M. vitrata* at 10 WAS, 5 - % *M. vitrata* populations in cowpea pods sampled 10 WAS, 6 - % dried cowpea pod damage by *M. vitrata* at harvest, 7 - % cowpea pod damaged by CPSB at harvest, 8 - % grain damaged by *M. vitrata* in 300 g, 9 - % grain damaged by CPSB in 300 g, 10. Post spray populations of CPSB 10 WAS, 11 - 100 cowpea grain weight (g), Pearson Correlation Coefficient for a Two-tailed test at df - (N-2) at * $P \leq .05$ (r - 0.250) and at ** $P \leq .01$ (r - 0.325).

Table 3: Combine Correlation among Damage Parameters during 2015 and 2016 Cropping Seasons

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	1.000										
2	-0.038NS	1.000									
3	0.129NS	0.766**	1.000								
4	0.169NS	0.286*	0.224NS	1.000							
5	0.141NS	0.166NS	0.120NS	0.751**	1.000						
6	-0.195NS	0.211NS	0.233NS	0.010NS	0.080NS	1.000					
7	-0.420**	-0.001NS	0.127NS	-0.358**	-0.294*	0.134NS	1.000				
8	-0.265*	0.244NS	0.344**	-0.203NS	-0.289*	0.283*	0.289*	1.000			
9	-0.191NS	0.406**	0.487**	0.371**	0.242NS	0.180NS	0.140NS	0.304*	1.000		
10	-0.071NS	0.201NS	0.143NS	0.019NS	-0.005NS	0.131NS	-0.033NS	-0.009NS	0.159NS	1.000	
11	0.155NS	-0.080NS	-0.184NS	0.092NS	0.100NS	-0.142NS	-0.322NS	-0.436**	-0.436**	0.025NS	1.000

Key: 1 - Yield (kg ha^{-1}), 2 - Post spray *M. vitrata* populations in flowers at 10 WAS, 3 - Post spray flower damage by *M. vitrata* at 10 WAS, 4 - % cowpea pod damage by *M. vitrata* at 10 WAS, 5 - % *M. vitrata* populations in cowpea pods sampled 10 WAS, 6 - % dried cowpea pod damage by *M. vitrata* at harvest, 7 - % cowpea pod damaged by CPSB at harvest, 8 - % grain damaged by *M. vitrata* in 300 g, 9 - % grain damaged by CPSB in 300 g, 10. Post spray populations of CPSB 10 WAS, 11 - 100 cowpea grain weight (g), Pearson Correlation Coefficient for a Two-tailed test at df - (N-2) at * $P \leq .05$ (r - 0.250) and at ** $P \leq .01$ (r - 0.325).

DISCUSSION

Associations among various damage indices of post-flowering insects showed significant positive and negative correlations at the indicated probability levels. However, a strong positive correlation (r>0) was observed in all years, and the combined effect on cowpea yield indicates that damage to flowers and pods is proportional to the populations of these insects. Yield depends heavily on the number of flowers that survive to pod formation. This means that the productivity of successful pod formation in cowpea depends on the availability of flowers that successfully transform into pods. This is a clear indication that damage to flowers is directly connected to an increase in M. vitrata and other complex pod-sucking bug populations. This is in line with the observations of Doumbia *et al.* (2019), who identified damage intensity caused by flower bud thrips as a function of their population. The more the increase in pod-borer population and pod-sucking bugs, the higher the damage and consequently the lower the cowpea yield. The significant correlation between flower infestation and damage also showed that *M. vitrata* and CPSBs are among the cowpea yield-limiting biotic factors in Sudan and similar ecologies. Maina *et al.* (2016) also reported that severe damage to flowers and cowpea pods 21 days after anthesis could affect cowpea grain yield. Consequently, they suggested that an insecticide must be applied in the third week after anthesis, during the late-flowering and early pod-filling stages. The observed relationships also emphasize the cumulative effect of pest complexes rather than the influence of a single species. The combined activity of *M. vitrata* and pod-sucking bugs amplified reproductive damage, resulting in compounded yield losses. This interaction explains the strong correlations between multiple damage indices and yield components. The negative correlation (r<0) obtained in this study corroborates the findings of Ajeigbe et al. (2012), who observed significant negative correlations between cowpea grain yield and cowpea flower infestations in a study conducted in Samaru, northern Guinea Savanna. Damage attributed to M. vitrata and pod-sucking bugs was reported to substantially reduce pod formation and subsequent grain yield, resulting in strong negative correlations between damage intensity and yield, as observed by Mukaka (2012) and Oerke (2006).

Conclusion

Post-flowering insect pests represent the most critical constraint to cowpea production in tropical agro-ecosystems. The pod-sucking bugs (*Clavigralla tomentosicollis* and *Anoplocnemis curvipes*) are particularly destructive due to their direct impact on reproductive structures. The insect caused damage mainly by their piercing and sucking feeding on the sap. Heavy infestation often leads to empty pods and shriveled grains. Understanding the diversity, biology, and damage patterns of these pests is essential for designing effective and sustainable pest management strategies to improve cowpea productivity and food security. Alternating sowing dates to avoid periods of high pod populations and minimizing insecticide use are crucial for reducing high pod populations and associated damage, thereby increasing yield and economic returns for farmers in the study area.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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