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Original Research

Evaluation of sowing date and insecticides for the management of viruses and insect vectors on Lentil (*Lenes Culinaris* Medikus) in North Shewa, Ethiopia

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ABSTRACT

Ethiopia is the leading lentil producer in Africa, yet national productivity has been in steady decline, driven by the rapid emergence of viral diseases and severe infestations of the pea aphid (*Acyrthosiphon pisum*). A field experiment was conducted at Enewari North Shewa during the 2022 and 2023 main cropping seasons to identify the best options for managing emerging lentil viruses and vectors. The experiment was laid out in a Randomized complete block design with four replications. The lentil variety Derso was integrated with two insecticides (profenophos 50% EC and Dimethoate 40% EC), including an untreated check, and four sowing dates were used as treatments. Virus disease incidence and Pea aphid population were recorded, yield and yield-related parameters were collected, and data were analyzed using R software. The outcomes revealed that insecticides combined with sowing date significantly reduced aphid populations and reduced virus incidence in lentil. Minimum number of Pea aphid infestation and low virus incidence (11%) recorded when planting lentil in the first week of August and spraying Dimethoate 40 % EC two times at a 7-day interval. Whereas the maximum number of pea aphids (35) and high virus incidence (22%) were recorded on untreated checks, indicating that the level of disease controlled by controlling the vector pea aphid accounts for 50%. Again, the highest seed yield (3303 kg) was obtained by spraying Dimethoate and planting lentil in the first week of August, compared with the low yield from the untreated check (1993 kg). Hence, integrating sowing date with Dimethoate in the first week of August resulted in 69.8% yield increments over the untreated. In general, the results indicated that virus and aphid vector management can be achieved by applying Dimethoate and adjusting the sowing date for lentil crops.

Keywords: *Insecticide, lentil, sowing date, vectors management, virus.*

INTRODUCTION

Lentil *(Lenes Culinaris* Medikus) is a high value profitable pulse crop if properly managed. Most of the production of lentil done by in the developing world, approximately 75%. Rawal and Navaro (2019) and FAO (2021) reported that Canada, India, Australia and Turkey are the biggest producer of lentil, accounting for 68% of global lentil production. In 2019 season, Ethiopia alone produced 119329 metric tons of lentil which made the country top in production and area coverage in Africa (FAOSTAT, 2019, FAOSTAT, 2023).

The major lentil producing regions in Ethiopia are Amhara, Oromia, Tigray and Southern Nations, Nationalities and Peoples (SNNP), which produced 61,142 t, 43,881 t, 25 t and 59 t, respectively, in the 2019/2020 cropping season (CSA, 2020). Ethiopian lentil is produced in the central highland plateau mainly following the black Vertisol distribution. It is also produced on light soils and loam soils. Generally, well drained soils with nearly neutral PH are suitable for lentil production. Lentil is a major *rabi* pulse crop and is known for its protein rich grains (Kumar, 2022).

The straw and the haulm are used as animal feed, and it ameliorates soil fertility through atmospheric nitrogen fixation and in so doing reducing the fertilizer requirement of the succeeding crop by about a third to a half. However, lentil yield in Ethiopia has been declining since the late 2010s and the country has turned from net exporter to importer. Although, several factors are attributed to the production decline, the recurrent occurrence of viral and fungal diseases, unavailability of improved seeds and poor extension system are among major constraints (Bekele and Tesfaye, 2023).

The production system is constrained by abiotic as well as emerging and regular biotic factors. Among the abiotic factors, climate changes have affected the crop, which appear to be dynamic. Out of the biotic factors pea seed borne mosaic virus and chickpea chlorotic stunt virus diseases are spreading at an alarming rate. Similarly, insect pests including aphids (*Acyrthosiphon pisum*), and the postharvest bruchids (Callosobruchus chinensis) are pressing the lentil crop survival (Rashed *et al.* 2018)

The pea aphid (*Acyrthosiphon pisum*) is a significant threat to lentil in the study area and the cool central highlands of north Shewa. Ioannis Zafeiriou 2022, said that (*Acyrthosiphon pisum*), became great challenge in temperate zone rainfed systems. *Acyrthosiphon pisum* is a serious concern for commercial pulse producers because it can injure the crops directly by removing sap from leaves, stems, and pods, and indirectly by acting as a vector for over 30 plant viruses, including cucumber mosaic virus, beet yellows virus, pea enation mosaic virus, and bean leafroll virus (paudel 2018, Rashed *et al.* 2018).

There are seed born and vector born virus which transmitted by piercing sucking insects such as aphids, thrips, leaf hoppers and stink bugs. *Aphis craccivora* commonly known as the cowpea aphid, black legume aphid, or groundnut aphid and *Acyrthosiphon pisum* (commonly known as green pea aphid) are a vector of the Alfalfa virus, Cucumber mosaic virus (CMV), and Lentil tobacco streak virus. Yield is drastically reduced if infestations are early and severe (Makkoukand Kumari, 2001). The productivity of lentil crops influencing primarily due to increased outbreaks of green pea aphids (*Acyrthosiphon pisum*) on lentils feed on several grain legumes (Rachid boulamtat and Seid Ahmed). Field peas, alfalfa and clovers are the main hosts of the pea aphid. Other legumes, including lentils, faba beans, vetches, sweet clover, sweet peas, trefoil and dry beans are also hosts (Anamika Sharma et al. 2021).

The action threshold is 1-2 aphids per leaf and 9-13 aphids per sweep. They suck the sap and colonize in large numbers and secrete powdery, sugary material. They cause sooty mold on the plants (Anamika Sharma et al. 2021). Various Viral diseases have recently become major production constraints in lentil and chickpea production area of the country particularly in central part of Ethiopia and north Shewa (Ademe *et al*., 2023; Kumari et al., 2019).

There was no readily available control measure for virus management; Hence, this field experiments were initiated to identify the best vector and virus management practices to reduce biomass and seed yield losses.

METHODS

The experiment was carried out at Enewari research station of Debre Birhan Agricultural Research Center (DBARC) for two years 2022 and 2023 main cropping season (Figure 1). The research station is located at 9° 25' 06" North and 39°10' 40" East at an altitude of 2680 m.a.s.l with mean annual rainfall of 988 mm. The average maximum and minimum temperature of the area was 21.4 and 9.0℃, respectively. The soil type of the experimental site is classified as vertisol with clay loam texture.

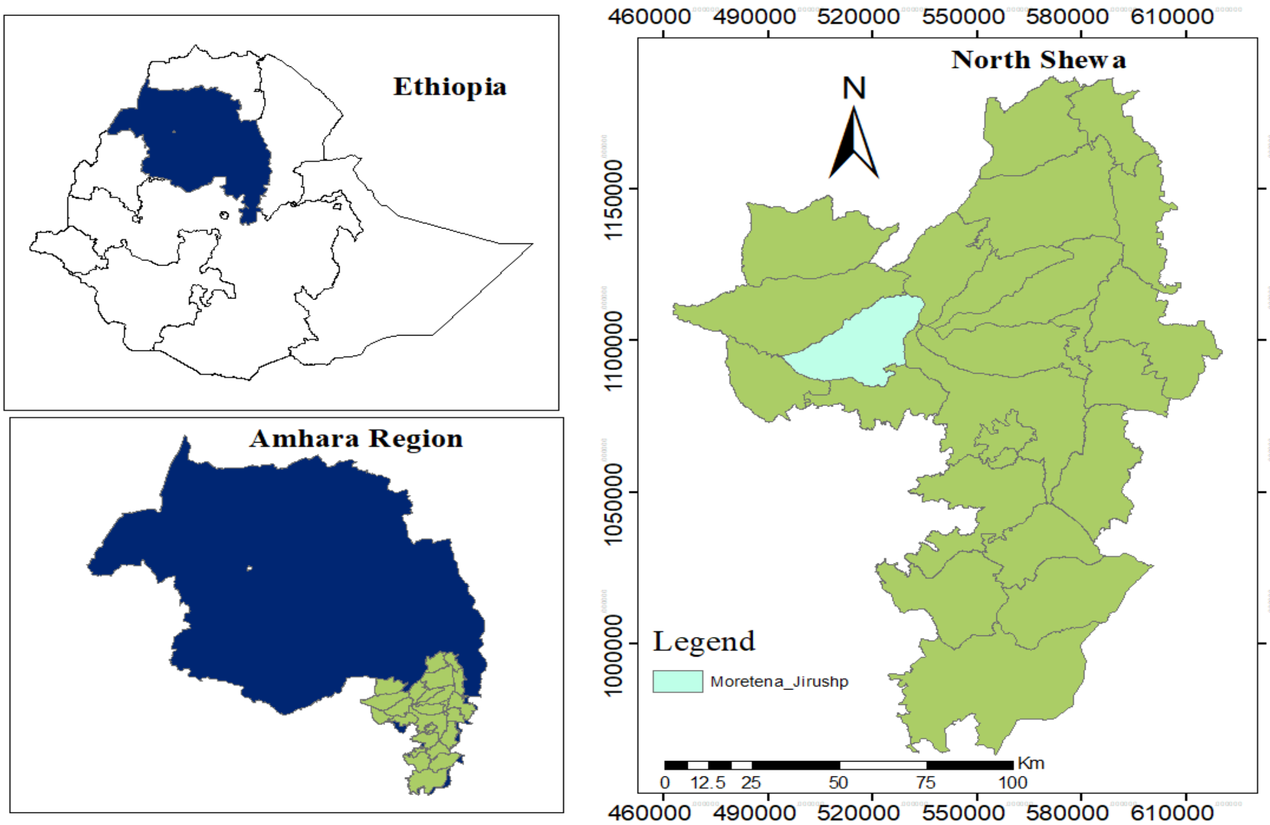


Figure 1. Map of the study area

Treatments and Experimental Design

Four sowing dates 25th of July. August 2, August 9 and August 15 and two insecticide (Dimethoate 40% EC and Profenofos 50% EC) spray and unsprayed control treatments combination. Totally, 12 treatments combination (Table 1) were used in factorial arrangement in randomized complete block design with four replications. The insecticide Dimethoate was treated at the rate of 1 l /ha and Profenofos at the rate of 0.75 l /ha in 150L/ha of water. The two insecticides were applied as soon as aphids were observed on lentil and a total of two sprays were applied. Plot size were 2 x 3m = 6m^2 /treatments with a total plot size of 2m (0.8m bed width and 0.4m furrow) x 3m = 6m^2 used/. The spacing between plots, rows, and blocks were 0.7m, 0.2m, 1.5m, respectively. Each experimental plot was consisted of 4 rows at each sub plot but, the 2 central rows were used for aphid count and viral disease incidence (%) score.

Data collected

Viral diseases, and their incidence (%) were recorded on the basis of symptoms (reddening, yellowing). Insect vector Pea aphids counted was done at weekly intervals starting from the appearance of insect to their appearance Aphids sampled by gently beating lentil plants on 20 cm by 39 cm counting board, carton plastered inside with white plastic sheet. The board was subdivided in to six 10 cm x 13 cm rectangles

(Tebekew, 2017). At each sampling spots, pea aphid dislodge on the counting board was counted from randomly chosen four rectangles. The board used to shake the plant above it one day before and after each spray. The normality of the aphid count and disease incidence % data were checked and there was no need for data transformations. In addition, Days to flowering, physiological maturity, number of pods, number of seed per plant and Plant height (PH)were taken. Biomass yield, grain yield and Hundred seed weight (HSW) also collected.

Table 1. Treatment arrangement and Experimental design

No	Treatments	Dose (kgha^{-1})
1	Sowing date 1(25 July) +Dimethoate 40%EC	1li/ ha^{-1}with 150li of water
2	Sowing date 1(25 July) + *Profenofos (50%) EC*	0.75li/ ha^{-1} with 150li of water
3	Sowing date 1(25 July) +untreated control	
4	Sowing date 2(2 Aug) +Dimethoate 40%EC	1li/ ha^{-1}with 150li of water
5	Sowing date 2(2 Aug) + *Profenofos (50%) EC*	0.75li/ ha^{-1} with 150li of water
6	Sowing date 2(2 Aug) +untreated control	
7	Sowing date 3(9 Aug) +Dimethoate 40%EC	1li/ ha^{-1}with 150li of water
8	Sowing date 3(9 Aug) + *Profenofos (50%) EC*	0.75li/ ha^{-1} with 150li of water
9	Sowing date 3(9 Aug) +untreated control	
10	Sowing date 4(15 Aug) +Dimethoate 40%EC	1li/ ha^{-1}with 150li of water
11	Sowing date 4(15 Aug) + *Profenofos (50%) EC*	0.75li/ ha^{-1} with 150li of water
12	Sowing date 4(15Aug) +untreated control	

Data analyses

Data collected across year were analyzed to assess the effectiveness of the insecticides and sowing dates for pea aphid management. Before doing the combined analysis of variance, the Bartlett's and Shapiro-Wilk tests were used to determine the homogeneity of error variance and the normality of the data, respectively. Data were analyzed using R-Studio version 4.4.0 (R Core Team 2021) using the packages "Ime" (Bates et al. 2015) and "emmeans" (Lenth, 2021).

Correlation analysis was used to determine the relationship among variables such as grain yield, aphid density (aphid count) virus severity, maximum temperature, minimum temperature, rain fall and relative humidity. For mean separation, Tukey Honesty Significance Difference test (HSD) was used at α = 0.05.

Cost-Benefit / economic Analysis

Actual yield was adjusted down ward by 10% to reflect the difference between experimental yield and farmers' yield. The price of lentil grains was computed during January 2024 based on the local market, costs that vary (TVC) like cost of Insecticide and labor to apply the insecticide was recorded and taken into account. Marginal rate of return was calculated using the formula as following.

Variable cost =chemical cost+ labor cost, Net benefit=sell revenue variable cost,

Marginal benefit =treated net benefit _un treated net benefit(control)

MRR= {(change Net benefit treated_ change of net benefit untreated)}/ (cost treated-cost untreated) *100

RESULTS AND DISCUSSION

Effect of treatments on seed yield and other agronomic traits of lentil

The effect of Insecticides (IC) showed significant difference on number of aphids after spray (AS) at (p<0.001) and on virus incidence at (p<0.01) in addition Maturity date (MD), hundred seed weight (HSW), biomass yield (BY) and Grain yield (GY) have showed significant difference (at p<0.05 and p<0.01) respectively. Besides the sowing date (SD) treatment has resulted in significant difference on virus incidence at (p<0.01) plus on number of aphid population and Maturity date (MD) significant difference observed at (p<0.05). On the other hand, the interaction effect (insecticides and sowing date) showed significant difference on flowering date and maturity date at (p<0.001) and for the number of aphids and virus incidence at (p<0.05) (Table 2).

Table 2. Main effect and interaction effect of insecticide and sowing date on vector aphid population and yield related variables.

SV	Df	Virus incidence	Number of Aphids BS	Number of Aphids AS	FD	MD	HSW	BY	GY
Rep	3	NS	NS	NS	NS	NS	NS	NS	NS
IC	2	**	NS	***	NS	*	*	*	**
SD	3	**	NS	*	NS	*	NS	NS	NS
IC*SD	6	*	NS	*	***	***	NS	NS	NS
CV (%)		7.4	5	30	4	2	5.6	22	25
LSD			1.6	8	1.9	3.6	0..2	1788	928

, **, * indicates significance at 0.05,0.01 and 0.001 probability levels, respectively SV= source of variation, Rep= Replication, IC= Insecticide, SD= Sowing date, NS = non-significant, BS =Before Spray, AS=After Spray FD= Flowering Date MD = Maturity Date HSW= Hundred seed Weight BY= B0omass yield GY= Grain Yield.*

Significant difference between treatments were observed in days maturity, 15Aug + Unsprayed showed maximum (120 days) and 9Aug+Profenofos 50% (111days) least day to maturity. In all treatment there was significant at (p<0.05) in Biomass yield (Table 3).

Table 3. Effect of Insecticides and sowing dates on yield and yield related parameters combined over year

Treatments	FD	MD	TNP	TNS	BY (kg ha-1)	GY (kgha^{-1})	HSW (g)
25Jul+ D	56C	117b	53ab	88ab	6424ab	2873abc	2.7abc
2Aug+D	58bc	117b	56ab	107ab	6909a	3303a	2.7abc
9Aug+D	55cd	112cd	43ab	76b	6123ab	2544abc	2.8ab
15Aug+D	62ab	112cd	51ab	90ab	5462ab	2634abc	2.6abc
25Jul+P	55cd	115bc	49ab	90ab	5702ab	2677abc	2.7abc
2Aug+P	57c	117b	64a	105ab	5984ab	2897abc	2.8a
9Aug+P	52d	111d	55ab	116a	4824b	2011ab	2.7abc
15Aug+P	61ab	115bcd	57ab	101ab	6420ab	2161bc	2.7abc
25Jul+Un	56c	115bc	40b	91ab	4999b	2264bc	2.5bc
2Aug+Un	56c	114bc	60ab	115a	4993b	2183bc	2.6abc

9Aug+Un	55cd	115bc	44ab	93ab	4834b	1976c	2.5bc
15Aug+Un	64a	120a	58ab	104ab	4828b	1993c	2.5c
CV (%)	4	2	30	23	21	25	5.6
LSD	1.9	3.6	13.3	36	1788	928	0.2

NB. D=Diemethoate (40%) EC, P= Profenofos (50%) EC, Un= untreated Check, 25 Jul to Aug 15 = Time of Sowing date TNP =Total Number of Pod, TNS =Total Number of seed, BY =Biomass yield, GY=Grain yield, HSW=Hundred seed weight

Higher grain yield 3303kg and biomass yield 6909kg obtained from 2Aug + Diemethoate in contrary to 15Aug + untreated check (4828kg). Grain yield percent reduction due to pea aphid was highly significantly (69.8%) different (p<0.01) among treatments. On other hand HSW also resulted in significant difference compared with un treated check (Table 3).

Disease incidence and symptomatology

Aug15 + Profenofos 50% (5%) Dimethoate sowing date two (11%) and Aug 9 + profenofos 50% (15%) recorded low percentage of severity. While other treatments invited greater than 15% disease severity (Fig 2). %) This result is in line with (Arash Rashed et al. 2018) the older the plant is prior to infestation the better able it is to withstand aphid injury.

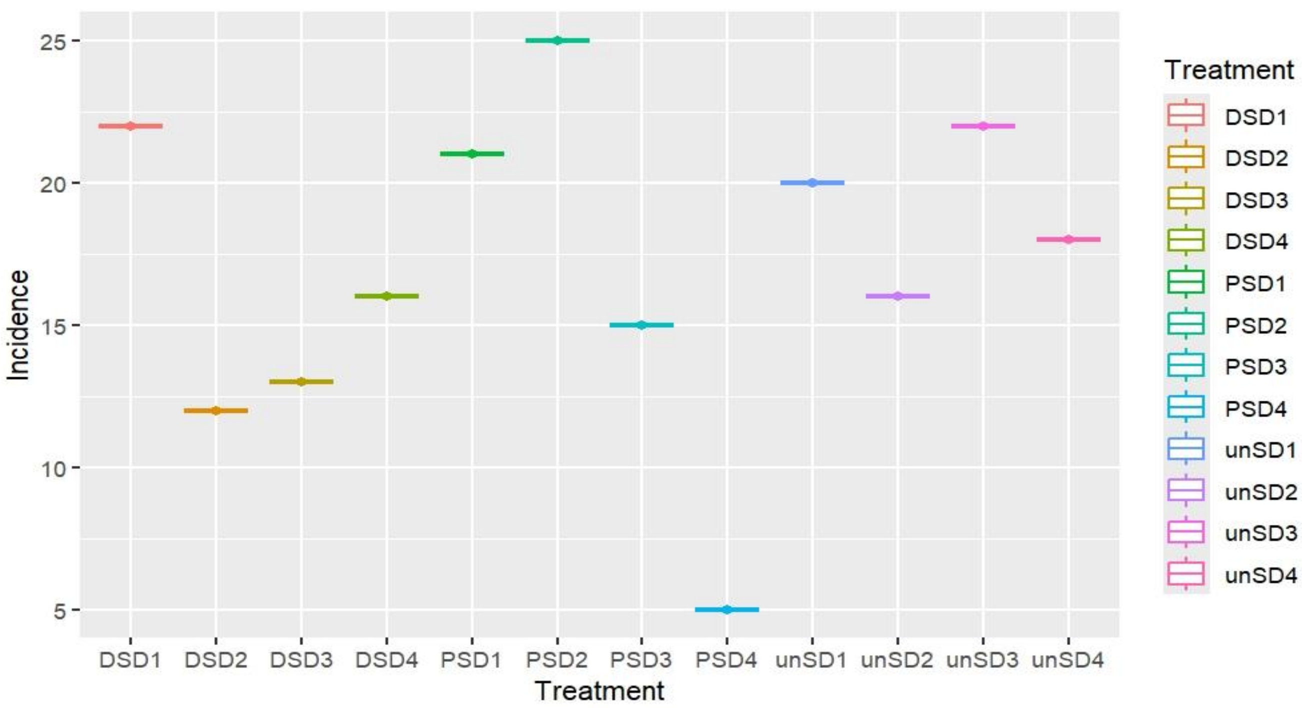


Figure 2. Disease incidence (%) between treatments on lentil Enewari

NB. D=Diemethoate (40%) EC, P= Profenofos (50%) EC, Un= untreated Check, SD1 to SD4 = Time of Sowing date

Symptomatology

The result revealed a wide spread occurrence of Lentil leaf Redding and Yellowing virus symptom recorded (Fig 3).

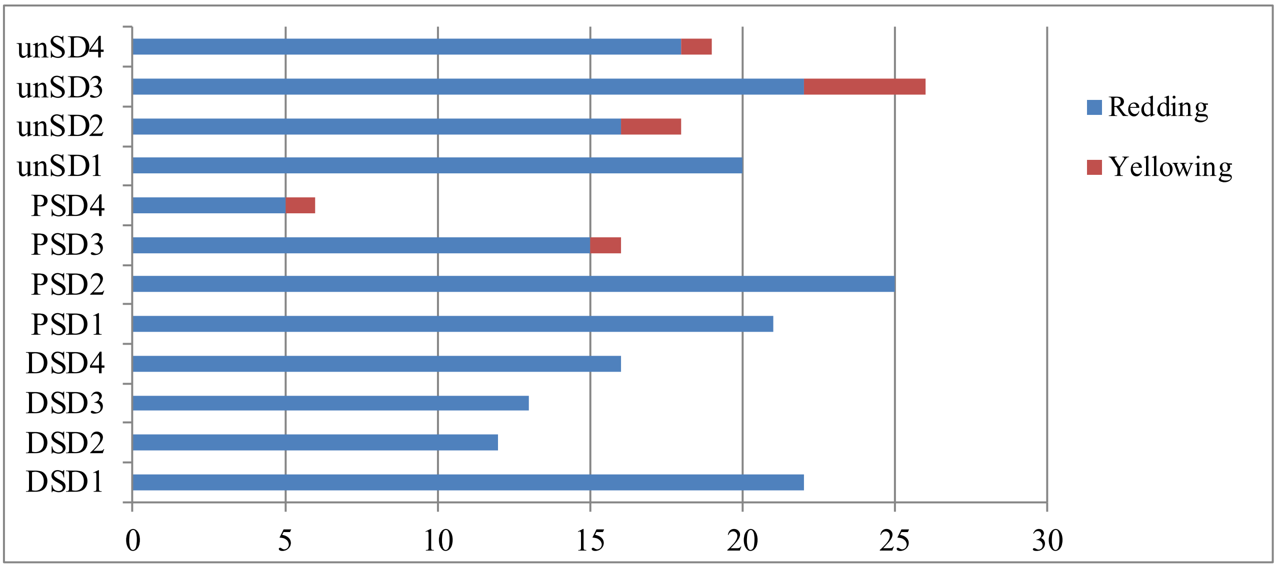


Figure 3. Virus symptom occurred among treatments on lentil Enewari

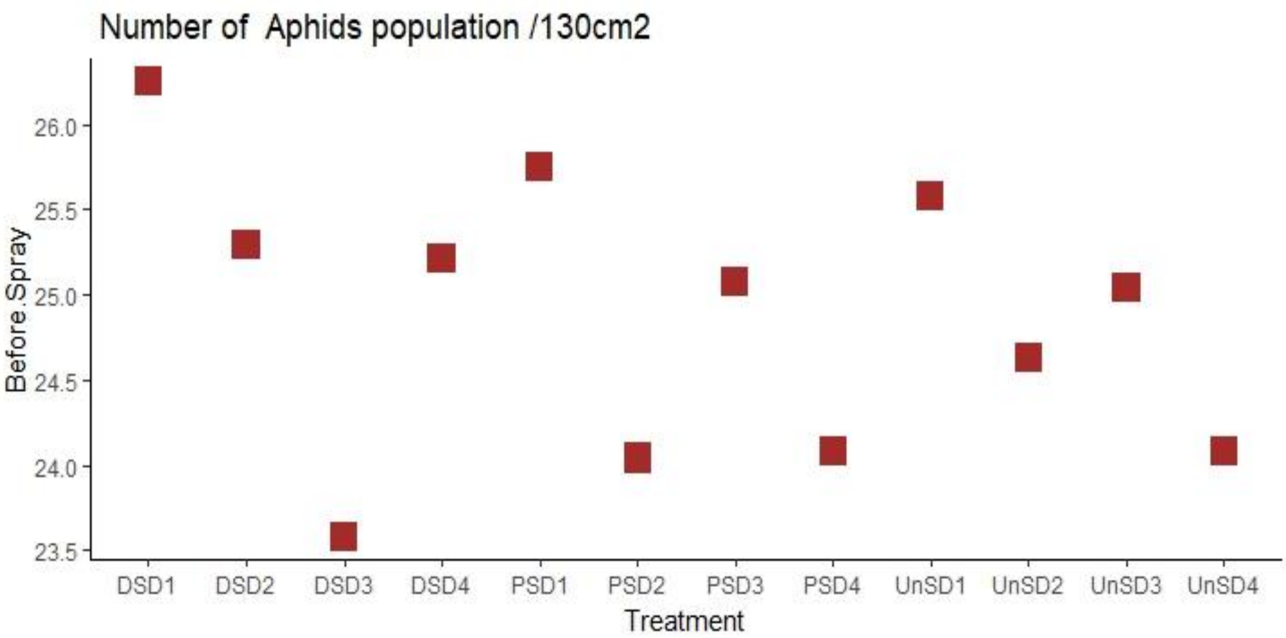
NB. D=Diemethoate (40%) EC, P= Profenofos (50%) EC, Un= untreated Check, SD1 to SD4 = Time of Sowing date

25 Jul + Diemethoate to 15Aug + Dimethoate sowing date and 25 Jul + profenofos and 2 Aug + Profenofos recorded only Redding.

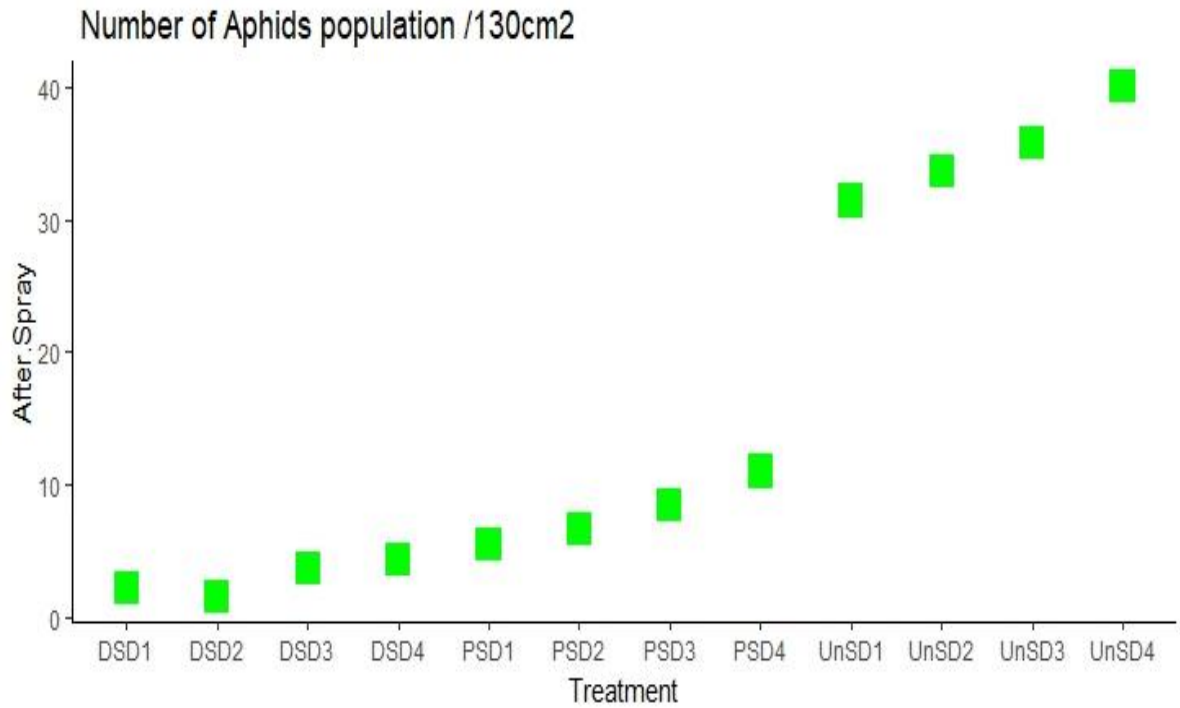
Least percent virus symptom observed on 2 Aug + Dimethoate and 9 Aug Dimethoate and 15 Aug + profenofos (Figure 3).

Effect of insecticide and sowing date on aphid population

Insecticides application was done after occurrence of pea aphid. data on aphid population taken before and after spray. All treatments recorded in greater than 23.5 aphid population before spray (Fig 4, A). Treatment Aug 2 + Dimethoate and 9Aug+ Dimethoate invite low number of aphids population and better control (Fig 4, B).



(A) Pea aphid Before spray



(B) Pea aphids After spray

Figure 4. Effect of insecticide and Sowing date on Pea aphid population before and after spray on lentil Enewari

Correlation of Weather parameters with agronomic traits and insect vector

Maximum temperature (°C) had positive correlation with virus incidence and mean number of aphid (r= 0.87*) and (r= 0.95*) respectively. High Temperature generally increase aphid reproduction and also stress plants, making more vulnerable to aphid feeding cause physiological changes under heat stress. Mean number of aphids population had positive correlation with virus incidence (r=0.77*) whereas Rf (r= -0.13) and RH (r= -0.85*) had negative correlation with number of aphids (Table 4). This result in line with variation in aphid population was mostly due to weather related factors i.e., temperature, rainfall, humidity, etc. Sowing time and variety might also be a potential reason for deviation in a number of aphids/plants; which was well studied by (Islam 2009). El Fakhouri (2021) annotated similar results on the population dynamics of pea aphid (*Acyrthosiphon pisum* Harris) infested at different standard meteorological week (SMW) on lentil cultivars. There was a highly significant linear relationship between the virus incidence and yield: as the virus incidence increase, the yields decreased. In contrary, sowing date on the first week of August with applying dimethoate minimize virus incidence (r=-0.67*) and vector population (r= -0.85) result in increased seed yield (r=0.83*).

Partial budget analysis for Integrated virus and vector management

Dominance analysis is the precondition before conducting economic analysis to identify the dominated treatments for which the net benefit decreased while cost that varies increased. Hence 9Aug + Dimethoate, 15Aug+Dimethoate, 25Jul + Profenofos, 25Jul+Dimethoate and 15Aug+Profenofos treatments are dominated so these treatments are excluded from economic analysis. Economic analysis was done for treatments 2Aug+Dimehoate, 2Aug +Profenofos and 9Aug + Profenofos. The economic analysis result revealed that 2Aug + Diemethoate at second sowing date have given higher net benefit (235444) and marginal rate of return (1177) followed by 9Aug + profenofos gained 214370 net benefit 451 marginal rate of return (Table 5).

Table 4. Correlation of Sowing date tested, Virus incidence and aphid population on lentil yield in relation to metrological factors 2022 and 2024

Parameters	Tmax (°C)	Tmin (°C)	Rf(mm) _	RH	Mean aphid population /130cm^2	Virus incidence	Di Sprayed FWAug	Seed Yield
Tmax (°C)	1							
Tmin (°C)	0.82*	1						
Rf(mm)	-0.3	0.05	1					
RH	-0.98	0,79*	0.64*	1				
Mean aphid population/130cm^2	0.95**	0.56	-0.13	-0.85*	1			
Virus incidence	0.87*	0.66	-0.2	-0.57	0.77*	1		
Di Sprayed FWAug	0.68	0.2	0.72	0.63*	-0.85*	-0.67*	1	
Seed Yield	0.75*	0.54	0.76	0.57	-0.86*	-0.7	0.83*	1

*Tmax- maximum temperature, Tmin- minimum temperature, RH- relative humidity, Rf-rainfall, °C- degree centigrade, mm- millimeter, %- percentage, Di Sprayed FWAug= Dimethoate Sprayed First Week of August, * Significant at 5% level of significance, ** Significant at 1 % level of significance*

Table 5. Economic anaysis

Treatments	Y(kgha1)	Adj.Y(kg ha)	Price GrY	Gross benefit (ETB ha)	Insecticides cost 2times	Labor cost 2 times	TVC ETB ha	NB (ETB ha)	MRR%
9Aug+Un	1976	1778.4	80	142272	0	0	0	177840	
2Aug+Un	2183	1964.7	80	157176	0	0	0	196470	
25Jul+Un	2264	2037.6	80	163008	0	0	0	203760	
15Aug+Un	2160	1944	80	155520	0	0	0	194400	
25Jul+P	2677	2409.3	80	192744	1500	150	1650	191094 D	
2Aug+P	2897	2607.3	80	208584	1500	280	1780	206804	171
25Jul+D	2873	2585.7	80	206856	1800	250	2050	204806 D	
2Aug+D	3302	2971.8	80	237744	1800	500	2300	235444	1177
9Aug+D	2543	2288.7	80	183096	1800	550	2350	180746 D	
9Aug+P	3010	2709	80	216720	1500	850	2350	214370	451
15Aug+D	2633	2369.7	80	189576	1800	600	2400	187176 D	
15Aug+P	2160	1944	80	155520	1800	600	2400	153120 D	

Note: Y = Lentil yield, Adj. Y = Adjusted Lentil yield, TVC = Total variable cost, NB = net benefit, MRR = marginal rate of return, D = Dominated, D=Diemethoate (40%) EC, P= Profenofos (50%) EC, Un= untreated Check, 25 Jul to Aug 15 = Time of Sowing

CONCLUSIONS

This study found that the interaction effect of insecticide and sowing date resulted in significant difference on the number of aphids population, vector damage and virus incidence. So, in integrating sowing date with Dimethoate provide varying degree of protection on lentil from vector pea aphid's attack. Moreover, the systemic insecticide suggesting its potential in the integrated management of the vector pea aphid and percent reduction for virus disease incidence.

Utilizing Dimethoate with proper rate, frequency and planting lentil on first week of August have advantageous in reducing the vectors, pea aphids and virus incidence, virus distribution pressure besides it provides higher economic return and seed yield the utmost seed yield of (3303 kg) was also produced by spraying Dimethoate and planting lentil in the first week of August in contrast low yield obtained from untreated check (1993 kg). So that spraying Diemethoate 40 % EC 1li with 150li /ha two times at 7 days interval and planting lentil on first week of August helps for better pea aphid vector management and virus control. In general, the management of viruses and pea aphid vectors can be achieved through adjusting sowing date and applying Dimethoate for lentil crops.

Conflict of interest

The authors declare that they have no conflicts of interest regarding the publication of this review article.

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