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Impact of Weather Variability on Insect Pests and Natural Enemies in *Linum usitatissimum* L.

Ramanuj Vishwakarma [a], Ram Balak Prasad Nirala [b] and Shivasankar Acharya [c*]

[a] Department of Entomology, Bihar Agricultural University, Sabour, Bhagalpur, India.
[b] Department of Plant Breeding and Genetics, Bihar Agricultural University, Sabour, Bhagalpur, India.
[c] Department of Agronomy, Bihar Agricultural University, Sabour, Bhagalpur, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Experiments were conducted at the Research Farm of Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India, to study the population dynamics of insect pests in linseed varieties Neelum and Sabour Tisi-1 during the Rabi seasons of 2020-21, 2021-22, 2022-23, and 2023-24, using a plot size of 1000 m². Six insect pests belonging to six families and genera were recorded: linseed bud fly (*Dasyneura lini* Barnes), capsule borer (*Helicoverpa armigera* Hubner), cutworm (*Agrotis ipsilon* Hufnagel), melon thrips (*Thrips palmi* Karny), blossom thrips (*Frankliniella schultzei* Trybom), and green peach aphid (*Myzus persicae* Sulzer). Additionally, two natural enemies were observed: the ladybird beetles (*Coccinella septempunctata* L. and *Menochilus sexmaculatus* F.)

**Corresponding author: Email: acharya.ss@rediffmail.com;*

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and lynx spider (*Oxyopes* spp.), all associated with the linseed varieties Neelum and Sabour Tisi-1. Among the insect pests, the linseed bud fly (*Dasyneura lini* Barnes) was identified as the most dominant pest, followed by thrips and the capsule borer. The highest bud fly infestation (26.84%) was observed in the Neelum variety at the dough stage, which was 2.83 times higher than in the Sabour Tisi-1 variety. The maximum number of nymphs and adult thrips (15.68 per plant) was recorded in the Neelum variety, which was 2.40 times higher than in Sabour Tisi-1. The highest number of grubs and adult ladybird beetles was observed at 1.08 per plant and 1.42 per plant in the Neelum and Sabour Tisi-1 varieties, respectively. Bud fly infestation was highly significantly and positively correlated with both maximum and minimum temperatures (r = 0.90 and r = 0.93 in Neelum; r = 0.92 and r = 0.92 in Sabour Tisi-1). Conversely, it was highly significantly and negatively correlated with maximum and minimum relative humidity (r = -0.78 and r = -0.76 in Neelum; r = -0.82 and r = -0.76 in Sabour Tisi-1). In conclusion, the Neelum variety was found to be more susceptible to insect pest attacks, followed by the Sabour Tisi-1 variety.

Keywords: Insect-pest; linseed; Linum usitatissimum; natural enemies; predators; population dynamics; weather.

1. INTRODUCTION

Linseed (*Linum usitatissimum* L.), also known as flax, is one of the oldest oilseed crops, cultivated in approximately 47 countries for both seed oil and fiber. Globally, linseed occupies an area of 3.54 million hectares, producing 3.37 million tonnes with an average productivity of 951 kg per hectare [1]. In India, it is primarily grown as a Rabi crop, covering an area of 1.83 lakh hectares in marginal, sub-marginal, irrigated, rainfed, and *utera* conditions, yielding 1.11 lakh tonnes with a productivity of 605 kg per hectare during the 2020-21 seasons. The major linseed-growing states in India include Madhya Pradesh, Jharkhand, Uttar Pradesh, Chhattisgarh, Odisha, Bihar, and Maharashtra, collectively accounting for about 91% of the country's total area under linseed cultivation in 2020-21. In Bihar, linseed was grown on 8,090 hectares, yielding 6,860 tonnes with a productivity of 847 kg/ha during 2020-21, which is 1.40 times higher than the national average [2].

Linseed is a rich source of vegetarian omega-3 fatty acids, protein, dietary fiber, lignin, flax fiber, and essential micronutrients. However, its cultivation is affected by diseases and insect pests at various stages of growth, leading to significant reductions in yield and quality. Among the insect pests, linseed bud fly (*Dasyneura lini* Barnes), semi-looper (*Plusia orichalcea* F.), thrips (*Caliothrips indicus* Bagnall), and linseed caterpillar (*Spodoptera exigua* Hübner) are particularly significant [3]. Of these, the bud fly, *D. lini*, is the most destructive and specific pest of linseed, causing seed yield losses ranging from 40% to 80% [4]. Factors such as plant variety, species, temperature, humidity, rainfall, sunlight, and wind velocity significantly influence insect pest population fluctuations [5].

There is limited published research on linseed insect pests and their natural enemies under current changing weather conditions, particularly from southern Bihar. Therefore, this study was undertaken to understand the population dynamics of insect pests and their associated natural enemies in linseed varieties Neelum and Sabour Tisi-1.

2. MATERIALS AND METHODS

Experiments were conducted at the Research Farm of Bihar Agricultural College, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India, located at 25°15' North Latitude, 86°57' East Longitude, and an altitude of 46 meters above mean sea level. The study was carried out during the Rabi seasons from 2020-21 to 2023-24 (4 years) to investigate the population dynamics of insect pests in linseed and their natural enemies.

Two linseed varieties, Neelum and Sabour Tisi-1, were grown on a plot size of 1000 m². Recommended agronomic practices were followed throughout the crop's growth. To ensure accurate observations, the field was maintained chemical-free. Data on insect pest populations and their natural enemies were recorded for both linseed varieties. Insects and natural enemies collected from the field were brought to the laboratory for preservation and identification using available resources.

For data collection, five plants from each linseed variety were randomly selected to monitor the

population of thrips, aphids, spiders, and ladybird beetles. The presence of cutworms and capsule borers was observed by counting their numbers per square meter from five randomly selected spots within the field. The infestation of bud fly was assessed on five randomly selected plants in each variety by counting the fresh and infested buds. Cumulative infestations were calculated using the formula provided by Malik [6].

$$\text{Bud fly infestation (\%)} = \frac{\text{Infested buds}}{\text{Total number of buds}} \text{ X } 100$$

To study the effect of weather parameters on the population dynamics of insect pests in linseed and their natural enemies, weekly weather data - such as minimum and maximum temperatures, maximum and minimum relative humidity, and rainfall were obtained from the Meteorological Observatory at the Department of Agronomy, Bihar Agricultural University, Sabour. The population data were then analyzed for correlation with these weather parameters using correlation coefficient analysis were calculated in Microsoft Excel 2010 software.

3. RESULTS AND DISCUSSION

A total of six insect pests belonging to four families and four genera, along with two natural enemies belonging to two families and genera, were observed on the linseed varieties Neelum and Sabour Tisi-1 at Sabour, Bihar (Tables 1 and 2). Among the insect pests, the linseed bud fly (*Dasyneura lini* Barnes) was the most prevalent. Two noctuid pests, the capsule borer (*Helicoverpa armigera* Hubner) and cutworm (*Agrotis ipsilon* Hufnagel), were also identified as significant threats, second only to the linseed bud fly. Additionally, two species of thrips - melon thrips (*Thrips palmi* Karny) and blossom thrips (*Frankliniella schultzei* Trybom) - were found to infest the linseed crop, along with the green peach aphid (*Myzus persicae* Sulzer).

Among the natural enemies, two ladybird beetle species, *Coccinella septempunctata* L. and *Menochilus sexmaculatus* F. and the lynx spider (*Oxyopes* spp.) were observed preying on the insect pests of linseed. The damaging stages of these insect pests and natural enemies are detailed in Tables 1 and 2.

The findings of this study align with those reported by Pal [4], who documented twenty-five species of phytophagous arthropods across thirteen families and six different orders on flax in Kalimpong, West Bengal. Major insects recorded included the gram pod borer (*H. armigera*), aphid (*Myzus persicae*), shield bug (*Plautia fimbriata*), and leaf webber (*Nacoleia* sp.). Similarly, *H. armigera*, *M. persicae*, and *D. lini* were reported as major pests of linseed in Raipur, Chhattisgarh, by Patel [7]. Three thrips species, *Caliothrips indicus*, *T. tabaci*, and *T. angusticeps* were known to infest linseed in India and Pakistan [7, 8 and 9]. Additionally, Hurej [10] identified a total of thirty-three species and two genera of Thysanoptera on oil flax plants, with *Thrips angusticeps* being the dominant species irrespective of the linseed type. Furthermore, *D. lini*, *A. ipsilon*, *H. armigera*, and *S. obliqua* were noted as key pests in Assam by Borah [8], supporting the current study's results.

The presence of natural enemies such as *C. septempunctata* and *M. sexmaculatus* aligns with the findings of Malik [11], while reports on the rove beetle (*Paederus* sp.) and lynx spider on linseed are consistent with those of Patel [7].

The population dynamics of insect pests associated with linseed varieties Neelum and Sabour Tisi-1, along with their natural enemies, are presented in Tables 3 and 4, respectively. The following provides a summary of the population trends observed on variety Neelum.

The population of cutworms varied from 0.08 to 0.67 larvae per square meter, with the highest population recorded during the 9th and 10th Standard Meteorological Weeks (SMWs). The nymph and adult population of thrips exhibited an increasing trend from the 3rd to the 12th SMW, followed by a decreasing trend from the 13th SMW onwards. The thrips population ranged from 0.33 to 13.58 per plant. For aphids, peak populations were observed during the 4th and 5th SMWs, with population densities ranging from 0.25 to 2.84 nymphs and adults per plant. The capsule borer population reached a maximum of 1.83 larvae per square meter during the 8th SMW. Bud fly infestation at the dough stage varied between 0.33% and 26.84%, with the highest infestation (26.84%) recorded during the 13th SMW. The bud fly infestation showed an increasing trend from the 4th to the 13th SMW, followed by a decline from the 14th SMW onwards.

Regarding natural enemies, the spider population peaked during the 7th SMW, with 1.25 spiders per plant, while the highest population of ladybird beetles (1.08 beetles per plant) was recorded during the 8th SMW.

Table 1. Insect-pests of linseed crop at Sabour

Order	Family	Scientific name	Common name	Damaging stage
Diptera	Cecidomyiidae	*Dasyneura lini* Barnes	Bud fly	Maggot
Lepidoptera	Noctuidae	*Helicoverpa armigera* Hubner	Capsule borer	Caterpillar
Lepidoptera	Noctuidae	*Agrotis ipsilon* Hufnagel	Cutworm	Caterpillar
Thysanoptera	Thripidae	*Thrips palmi* Karny	Melon thrips	Nymph, Adult
Thysanoptera	Thripidae	*Frankliniella schultzei* Trybom	Blossom thrips	Nymph, Adult
Hemiptera	Aphididae	*Myzus persicae* Sulzer	Aphid	Nymph, Adult

Table 2. Natural enemies of pests of linseed crop at Sabour

Order	Family	Scientific name	Common name	Stage observed
Coleoptera	Coccinellidae	*Coccinella septempunctata* L., *Menochilus sexmaculatus* F.	Lady bird beetle	Grub, Adult
Araneae	Oxyopidae	*Oxyopes* spp.	Lynx Spider	Adult

Table 3. Incidence of insect pests and their natural enemies of linseed var. Neelum at Sabour (mean of 2020-21, 2021-22, 2022-23 and 2023-24)

SMW	Insect pests					Natural enemies	
	Cutworm (No./m^2)	Thrips (No./plant)	Aphid (No./plant)	Capsule borer (No./m^2)	Bud flies Infestation (%)	Spider (No./plant)	Lady bird beetle (No./plant)
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.17	0.33	0.25	0.00	0.00	0.08	0.25
4	0.25	0.92	1.75	0.08	0.33	0.17	0.42
5	0.42	1.50	2.84	0.42	1.83	0.50	0.67
6	0.50	2.58	1.67	1.09	4.17	0.75	1.00
7	0.33	4.17	1.17	1.42	7.00	1.25	1.00
8	0.33	7.75	1.17	1.83	10.00	0.75	1.08
9	0.67	10.42	0.75	1.42	12.33	1.08	0.75
10	0.67	11.08	0.50	1.25	16.50	1.17	0.83
11	0.33	13.50	0.83	1.58	22.33	1.08	0.67
12	0.17	13.58	0.25	0.92	23.17	0.75	0.33
13	0.08	7.00	0.00	0.67	26.84	0.50	0.42
14	0.00	3.17	0.00	0.33	20.83	0.33	0.33
15	0.00	0.92	0.00	0.08	16.00	0.17	0.08

SMW – Standard Meteorological Week

The results of the population dynamics of insect pests and natural enemies observed on linseed variety Sabour Tisi-1, as presented in Table 4, are summarized here.

The population of cutworms ranged from 0.17 to 0.50 larvae per square meter, with the highest population recorded during the 7th and 9th Standard Meteorological Weeks (SMWs). The population of thrips, including both nymphs and adults, ranged from 0.08 to 5.67 per plant. For aphids, the peak population (1.58 aphids per plant) was observed during the 5th SMW, with the overall population ranging from 0.08 to 1.58 nymphs and adults per plant.

The capsule borer population peaked at 1.42 larvae per square meter during the 11th SMW. Regarding bud fly infestation, an increasing trend was observed from the 4th to the 12th SMW, followed by a decline from the 13th SMW onwards. The bud fly infestation at the dough stage varied from 0.17% to 9.50%, with the highest infestation recorded during the 12th SMW.

Table 4. Incidence of insect pests and their natural enemies of linseed var. Sabour Tisi-1 at Sabour(mean of 2020-21, 2021-22, 2022-23 and 2023-24)

SMW	Insect pests					Natural enemies	
	Cutworm (No./m^2)	Thrips (No./plant)	Aphid (No./plant)	Capsule borer (No./m^2)	Bud flies Infestation (%)	Spider (No./plant)	Lady bird beetle (No./plant)
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.08	0.08	0.00	0.00	0.50	0.08
4	0.17	0.50	0.58	0.08	0.17	0.33	0.25
5	0.33	1.25	1.58	0.25	1.17	0.67	0.59
6	0.42	1.92	1.25	0.50	1.84	0.83	0.75
7	0.50	2.75	1.08	0.75	3.50	1.25	1.25
8	0.33	4.42	1.00	1.00	5.67	0.83	0.83
9	0.50	5.67	0.58	1.33	6.50	0.67	1.08
10	0.42	5.17	0.50	1.17	8.17	0.75	1.17
11	0.33	4.50	0.25	1.42	8.58	1.08	1.42
12	0.25	3.33	0.17	0.58	9.50	0.67	0.67
13	0.08	1.92	0.00	0.42	7.92	0.67	0.50
14	0.00	0.83	0.00	0.17	7.58	0.33	0.33
15	0.00	0.58	0.00	0.08	7.58	0.00	0.25

SMW – Standard Meteorological Week

Among natural enemies, the maximum spider population (1.25 spiders per plant) was recorded during the 7th SMW, while the ladybird beetle population peaked at 1.42 beetles per plant during the 11th SMW.

The population dynamics of insect pests across the two linseed varieties, Neelum and Sabour Tisi-1, showed variability in infestation levels. The cutworm population ranged from 0.08 to 0.67 larvae per square meter in both varieties, with the highest population observed during the 9th Standard Meteorological Week (SMW). Thrips populations exhibited fluctuating trends, with peak densities of 13.58 thrips per plant in Neelum and 5.67 thrips per plant in Sabour Tisi-1. The aphid population was highest in Neelum (2.84 aphids per plant) during the 5th SMW, followed by Sabour Tisi-1 (1.58 aphids per plant). Capsule borer populations peaked during the 8th and 11th SMWs with 1.83 larvae per square meter in Neelum and 1.42 larvae per square meter in Sabour Tisi-1, respectively.

The bud fly infestation was highest at the dough stage in Neelum, reaching 26.84%, which was 2.83 times greater than in Sabour Tisi-1. The spider population peaked at 1.25 spiders per plant during the 7th SMW in both varieties, while the maximum population of ladybird beetles was observed in Sabour Tisi-1 (1.42 beetles per plant) during the 11th SMW, followed closely by Neelum (1.08 beetles per plant).

Among the insect pests, the linseed bud fly was identified as the primary pest, followed by thrips, capsule borers, cutworms, and aphids. Bud fly infestation started during the 4th SMW and peaked at the dough stage in Neelum. Thrips reached a maximum population of 13.58 and 5.67 per plant in Neelum and Sabour Tisi-1, respectively, while the highest capsule borer densities were 1.83 and 1.42 larvae per plant in Neelum and Sabour Tisi-1, respectively. The population of ladybird beetles peaked at 1.08 and 1.42 per plant in Neelum and Sabour Tisi-1, respectively.

The findings align with previous research by Mishra [12], which identified the linseed bud fly, *D. lini* (Barnes), as a key pest across India. Similar observations were made by Gupta [13], who reported peak populations of thrips and spiders during the 10th and 9th SMWs, respectively. Earlier studies by [14, 15 and 16] also highlighted the significance of *H. armigera* as a major linseed pest. The present study's observations regarding spiders and ladybird beetles as dominant natural enemies support findings by Patel [7] and Prasad [17], who documented their role in pest population suppression.

Table 5. Correlation of weather parameters with insect-pest of linseed (var. Neelum) and their natural enemies at Sabour (mean of 2020-21, 2021-22, 2022-23 and 2023-24)

Particular	Max Temp (°C)	Min Temp (°C)	Max RH (%)	Min RH (%)	Rainfall (mm)	Cutworm (No./m^2)	Thrips (No./plant)	Aphid (No./plant)	Capsule borer (No./m^2)	Bud flies Infestation (%)	Spider (No./plant)	Lady bird beetle (No./plant)
Max Temp (°C)	1.00	-	-	-	-	-	-	-	-	-	-	-
Min Temp (°C)	0.97**	1.00	-	-	-	-	-	-	-	-	-	-
Max RH (%)	-0.94**	-0.89**	1.00	-	-	-	-	-	-	-	-	-
Min RH (%)	-0.90**	-0.79**	0.85**	1.00	-	-	-	-	-	-	-	-
Rainfall (mm)	0.26NS	0.42NS	-0.08NS	-0.12NS	1.00	-	-	-	-	-	-	-
Cutworm (No./m^2)	-0.02NS	-0.19NS	0.02NS	-0.13NS	-0.19NS	1.00	-	-	-	-	-	-
Thrips (No./plant)	0.52*	0.52*	-0.39NS	-0.41NS	0.49NS	0.48NS	1.00	-	-	-	-	-
Aphid (No./plant)	-0.35NS	-0.49NS	0.40NS	0.04NS	-0.26NS	0.55*	-0.09NS	1.00	-	-	-	-
Capsule borer (No./m^2)	0.35NS	0.23NS	-0.28NS	-0.44NS	0.07NS	0.67**	0.76**	0.25NS	1.00	-	-	-
Bud flies Infestation (%)	0.90**	0.93**	-0.78**	-0.76**	0.54*	-0.03NS	0.72**	-0.40NS	0.40NS	1.00	-	-
Spider (No./plant)	0.37NS	0.24NS	-0.36NS	-0.48NS	0.09NS	0.76**	0.76**	0.27NS	0.91**	0.42NS	1.00	-
Lady bird beetle (No./plant)	0.11NS	-0.06NS	-0.10NS	-0.34NS	-0.16NS	0.79**	0.43NS	0.60*	0.86**	0.08NS	0.82**	1.00

** Significant at p=<0.05 ; ** Significant at p=<0.01*

Table 6. Correlation of weather parameters with insect-pest of linseed (var. Sabour Tisi-1) and their natural enemies at Sabour (mean of 2020-21, 2021-22, 2022-23 and 2023-24)

Particular	Max Temp (°C)	Min Temp (°C)	Max RH (%)	Min RH (%)	Rainfall (mm)	Cutworm (No./m^2)	Thrips (No./plant)	Aphid (No./plant)	Capsule borer (No./m^2)	Bud flies Infestation (%)	Spider (No./plant)	Lady bird beetle (No./plant)
Max Temp (°C)	1.00	-	-	-	-	-	-	-	-	-	-	-
Min Temp (°C)	0.97**	1.00	-	-	-	-	-	-	-	-	-	-
Max RH (%)	-0.94**	-0.89**	1.00	-	-	-	-	-	-	-	-	-
Min RH (%)	-0.90**	-0.79**	0.85**	1.00	-	-	-	-	-	-	-	-
Rainfall (mm)	0.26NS	0.42NS	-0.08NS	-0.12NS	1.00	-	-	-	-	-	-	-
Cutworm (No./m^2)	0.06NS	-0.10NS	-0.04NS	-0.27NS	-0.04NS	1.00	-	-	-	-	-	-
Thrips (No./plant)	0.41NS	0.32NS	-0.33NS	-0.39NS	0.14NS	0.79**	1.00	-	-	-	-	-
Aphid (No./plant)	-0.26NS	-0.43NS	0.27NS	-0.06NS	-0.25NS	0.74**	0.28NS	1.00	-	-	-	-
Capsule borer (No./m^2)	0.39NS	0.28NS	-0.32NS	-0.41NS	0.02NS	0.79**	0.97**	0.28NS	1.00	-	-	-
Bud flies Infestation (%)	0.92**	0.92**	-0.82**	-0.76**	0.46NS	0.22NS	0.64*	-0.25NS	0.59*	1.00	-	-
Spider (No./plant)	0.16NS	0.04NS	-0.12NS	-0.37NS	0.10NS	0.81**	0.68**	0.57*	0.73**	0.32NS	1.00	-
Lady bird beetle (No./plant)	0.38NS	0.24NS	-0.35NS	-0.49NS	0.01NS	0.88**	0.88**	0.45NS	0.93**	0.54*	0.87**	1.00

** Significant at p=<0.05; ** Significant at p=<0.01*

Correlation analyses between weather parameters and insect pest populations (Table 5) indicated that thrips in Neelum had a significant positive correlation with maximum and minimum temperatures (r = 0.52 each). Bud fly infestation showed a strong positive correlation with maximum and minimum temperatures (r = 0.90 and r = 0.93) and a significant negative correlation with maximum and minimum relative humidity (r = -0.78 and r = -0.76). Rainfall also positively correlated with bud fly infestation (r = 0.54). Conversely, cutworm, aphid, and ladybird beetle populations were negatively correlated with maximum and minimum temperatures, while capsule borers and spiders were positively correlated.

In Sabour Tisi-1 (Table 6), bud fly infestation was significantly positively correlated with maximum and minimum temperatures (r = 0.92 each) and negatively correlated with maximum and minimum relative humidity (r = -0.82 and r = -0.76). Rainfall had a positive correlation (r = 0.46). Cutworm, thrips, capsule borers, spiders, and ladybird beetles were positively correlated with temperatures but negatively correlated with relative humidity. Aphid populations exhibited a negative correlation with temperature.

Overall, bud fly infestation was heavily influenced by temperature, showing a significant positive correlation with maximum and minimum temperatures and a significant negative correlation with relative humidity in both varieties. The correlation of thrips populations with temperature was notably stronger in Neelum. These findings are consistent with reports by Daharia [18], who observed that thrips populations in linseed were positively correlated with maximum temperatures and negatively correlated with morning relative humidity. Additionally, cumulative bud fly infestations were positively correlated with temperature and negatively correlated with relative humidity, consistent with findings by Gupta [13]. The population dynamics of *H. armigera* were negatively correlated with temperature, relative humidity, and rainfall, as previously reported by Kumar [19].

4. CONCLUSION

Based on the results obtained from both linseed varieties, it can be concluded that the variety Neelum exhibited greater susceptibility to insect pests compared to Sabour Tisi-1. However, Sabour Tisi-1 was more favorable for supporting the highest population of ladybird beetles, followed by Neelum. Bud fly infestation in both varieties was strongly positively correlated with maximum and minimum temperatures, while it showed a significant negative correlation with maximum and minimum relative humidity. This indicates that temperature plays a critical role in increasing bud fly infestation, whereas higher relative humidity acts as a limiting factor for its population build-up.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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