frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 13 March 2024
DOI 10.3389/fsufs.2024.1344224

Check for updates

OPEN ACCESS

EDITED BY
Matteo Balderacchi,
Independent Researcher, Piacenza, Italy

REVIEWED BY
Gustavo Silva,
São Paulo State University, Brazil
Zhongqi He,
United States Department of Agriculture,
United States
Engin Gönen,
Oil Seeds Research Institution, Türkiye

*CORRESPONDENCE
Abdul Fattah
✉ abdulfattah911@ymail.com
Muhammad Fitrah Irawan Hannan
✉ muhf003@brin.go.id

RECEIVED 06 December 2023
ACCEPTED 29 January 2024
PUBLISHED 13 March 2024

CITATION
Fattah A, Hannan MFI, Yasin M, Harnowo D, Nugraha Y, Wulanningtyas HS, Najamuddin E, Saenong S, Rahman AA, Winanda E, Hasanuddin R, Rohimatun, Sebayang A, Nurhafsah and Andriyani I (2024) The characteristics of several varieties and the effect of cropping management design on the level of pest damage and seed yield of soybeans in rainfed lowland rice fields. *Front. Sustain. Food Syst.* 8:1344224.
doi: 10.3389/fsufs.2024.1344224

COPYRIGHT
© 2024 Fattah, Hannan, Yasin, Harnowo, Nugraha, Wulanningtyas, Najamuddin, Saenong, Rahman, Winanda, Hasanuddin, Rohimatun, Sebayang, Nurhafsah and Andriyani. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

The characteristics of several varieties and the effect of cropping management design on the level of pest damage and seed yield of soybeans in rainfed lowland rice fields

Abdul Fattah[1]*, Muhammad Fitrah Irawan Hannan[1]*, M. Yasin[1], Didik Harnowo[1], Yudhistira Nugraha[1], Heppy Suci Wulanningtyas[1], Erwin Najamuddin[1], Sudjak Saenong[1], Ayyub Ar Rahman[1], Elisa Winanda[2], Rahmi Hasanuddin[1], Rohimatun[3], Amelia Sebayang[3], Nurhafsah[4] and Ida Andriyani[5]

[1]Research Organization for Agriculture and Food, Research Center for Food Crops, National Research and Innovation Agency, Bogor, Indonesia, [2]Research Center for Food Technology and Processing, Research Organization for Agriculture and Food, National Research and Innovation Agency, Bogor, Indonesia, [3]Research Center for Horticultural and Estate Crops, Research Organization for Agriculture and Food, National Research and Innovation Agency, Bogor, Indonesia, [4]Research Organization for Agriculture and Food, Research Center for Agroindustry, National Research and Innovation Agency, Tangerang Selatan, Banten, Indonesia, [5]Research Organization for Governance, Economy, and Community Welfare, Jakarta, Indonesia

Design of cropping method and type of variety are one of the most important factors in increasing soybean productivity and the level of pest attack and predator populations. This study aims to determine the most effective planting method and variety types in an effort to increase soybean productivity in rainfed lowland areas in South Sulawesi, Indonesia. The design used in this study was the split plot design, and the varieties (PU) used were as follows: (1) Detap-1, (2) Devon-1, and (3) Derap-1. However, the subplot (AP) was a planting method and three replicates: (1) farmer's transplanting method (transplanting row: 20 cm × 20 cm), (2) method of transplanting double rows, and (3) method of transplanting three rows. The results showed that the highest number of branchesper plant was observed in the Legowo three planting method with the Detap-1 variety. The lowest level of leaf damage due to *Spodoptera litura* attack was observed in the Legowo double rows planting method with the Devon-1 variety (11.07%), and the highest level of leaf damage was observed in the jajar horn planting method (farmer's method) with the Derap-1 variety (16.47%). The level of pod damage due to *Etiella zinckenella* attack was the lowest on Legowo three planting method on the Derap-1 variety (9.47%) and the highest on the Legowo double rows planting method on the Detap-1 variety (14.26%). The level of pod damage due to attack by pod-sucking pest *Riptortus linearis* was the lowest on Legowo three planting method on the (Derap-1) variety (8.02%) and the highest on the pod-sucking pest *Riptortus linearis* on the Devon-1 variety (13.43%). The length of the trichomes on soybean leaves was the highest on the Devon-1 variety (30.93%) and the lowest on Derap-1 (24.81). The highest number of trichomes on soybean leaves was on the Derap-1variety (57.67) and the lowest on the Devon-1 variety (32.20). The highest length of trichomes was on soybean pods on Detap-1 (29.11) and the lowest on Devon-1 (26.52), while the highest number of trichomes in soybean pods was on Devon-1 (222.47) and the lowest on Derap-1 (148.40). The highest seed yield was observed in Legowo three panting method with Derap-1 and Devon-1 varieties (2.02–2.08 t ha^{-1}).

KEYWORDS

soybean, characteristics, planting methods, varieties, pests, leaf damage, pod damage, seed yield

1 Introduction

Soybean is a legume plant that is extensively cultivated worldwide because it contains vegetable oil and it is a source of minerals and protein (Anderson et al., 2019; Khan et al., 2021; Otie et al., 2021). According to Bhatt et al. (2022), soybeans are also a source of vitamins and antioxidants. Furthermore, according to Singh and Krishnaswamy (2022), soybeans are useful as raw materials for the food, feed, fuel, and pharmaceutical industries. From the aspect of plant cultivation, soybeans can act as nitrogen-producing plants, which can increase soil fertility and reduce the use of chemical fertilizers (Chen et al., 2022).

Several major countries, including China, have cultivated soybeans (Prince et al., 2020; Zhao et al., 2021). Indonesia, as an agricultural country, has cultivated soybeans to meet food needs in the country through extensification or expansion of planting areas and intensification, such as the development of soybeans using technology including the use of new superior varieties (Kharisma, 2018). This system can increase land productivity, yield diversification, and farmer income (Han et al., 2022).

Soybean can be planted on suboptimal land, such as a dry land, a rainfed lowland rice field, and a tidal swamp land (Elisa Faizaty et al., 2016). In Indonesia alone, the area of rainfed rice fields reaches 3.71 million ha (± 45.7% of the total paddy fields; Kasno et al., 2016). Soybean productivity in rainfed lowland areas in South Sulawesi ranges from 1.7 to 2.3 t ha^{-1}, using superior varieties and improved cultivation techniques (Subandi and Anwari, 2012). If the soybean farming system developed in rainfed paddy fields can achieve an average productivity of 2.0 t ha^{-1}, the national target of soybeans toward soybean self-sufficiency can be achieved (Harsono et al., 2012).

Soybean productivity in Indonesia, including South Sulawesi, remains notably low, approximately 1.50–2.20 t ha^{-1} (Fattah et al., 2018). In addition, production values each year vary significantly. The production value in 2019 decreased by 0.23 million tons (64.6%) compared with 2018 production, which was 0.65 million tons [Direktorat Jendral Tanaman Pangan (Dirjentan), 2019]. While the demand for soybeans in Indonesia is quite high, in the end, the country has to import soybeans every year to meet the needs of its people. In February 2019, total soybean imports were nearly 217 thousand tons, an increase of 65% compared with February 2018 [Pusat Pengkajian Perdagangan Dalam Negeri (PPPDN), 2019].

To reduce imports in fulfilling soybeans, researchers are always trying to find innovative methods to increase soybean productivity. Research results (Supriono, 2000; Rasyd, 2013; Syafruddin et al., 2014) proved that the use of technology, such as the use of new superior varieties, spacing, and proper fertilization, could increase soybean productivity and farmers' income. One of the environmentally friendly technological innovations is the Legowo planting system, both Legowo 3 rows and Legowo 4 rows. Spacing is one of the technological components that can still be optimized, and controlling the number of plant populations is believed to increase soybean productivity per unit area (Mardian et al., 2019).

Double spacing (Legowo 2:1) can be done in an effort to increase the productivity because soybean plants require sufficient light. The optimum plant density to produce maximum productivity varies between plants, between genotypes, and between locations. Some research works show positive results in the application of Legowo cultivation. Some reported results are as follows: Sarkodie-Addo and Mahama (2012) reported that in Ghana, the spacing that gave the best results was 40 cm × 5 cm, while in Iowa, a narrow spacing of 38 cm increased the yields of 0.248 t ha^{-1}, which was higher than the 76 cm wide spacing that is usually practiced by farmers. In Adana, Turkey, soybean yield reached 5.82 t ha^{-1} with a spacing of 70 cm × 4 cm (Gulluoglu et al., 2017). Research (Srihartanto et al., 2015) showed that a plant spacing of 40 cm × 20 cm with the Legowo 2 system in Yogyakarta could increase the productivity of the highest Kaba soybean variety (2.94 t ha^{-1}). In Magelang, a spacing of 40 cm × 10 cm with the Legowo system can increase plant height, while a spacing of 40 cm × 30 cm with the Legowo system can increase the number of productive branches, dry stover weight, and a weight of 1,000 dry seeds (Nurbaiti et al., 2017). In the study by Santoso et al. (2020), the soybean pod damage inflicted by *E. zinckenella* was most pronounced at a planting spacing of 30 cm × 30 cm, reaching 22.67%. Conversely, Aji et al. (2019) reported that soybean leaf damage caused by grasshoppers (*Valangan* sp.) was highest at a planting spacing of 30 cm × 40 cm, registering at 26.94%, while damage induced by *S. litura* attacks on soybean leaves peaked at a planting spacing of 30 cm × 30 cm, reaching 33.6%.

Soybean cultivation design management techniques and the use of superior varieties are the ways to control pests in an environmentally friendly manner (Aryati and Ulina, 2023). Appropriate management followed by the use of environmentally friendly technologies has a positive effect on the environment and the sustainability of plant productivity (Yan et al., 2020; Singh and Krishnaswamy, 2022). Types of pests that often reduce productivity and quality and fail harvests in Indonesia, including South Sulawesi, are pod sucking pests (*R. linearis*), pod borer pests (*E. zinckenella*), and armyworm pests (*S. litura*) (Oliveira et al., 2014; Tetila et al., 2020).

In the United States, as one of the soybean exporting countries, yield losses due to insect attacks in 2019 reached USD $15 per ha, where *Nezara viridula* is the primary pest, followed by *Helicoverpa armigera* and other pests (Musser et al., 2020). The other results of the research also revealed that several pests have dominance and influence on the conditions of seed planting locations. The results of research at three research stations also revealed that the primary pests of soybeans in Arkansas include *Nezara viridula* and *Helicoperva zeae* (Kezar et al., 2023).

This study aims to determine the most effective planting method and variety types in an effort to suppress pest attacks and increase soybean productivity in rainfed lowland rice fields.

2 Materials and methods

This research was conducted in Toddolimae Village, Tompobulu District, Maros Regency, South Sulawesi, Indonesia, in 2021, located at 5.085324°S and 119.6535983°E. This area has an alluvial soil type, a height of 500 m above sea level, and experiences average rainfall (data angka). The climate conditions during the research period were from April to September, the temperature ranged from 24.1 to 24.8 Ċ, and humidity ranged from 77 to 84% (Maros Regency Central Statistics Agency, 2022). The soil texture at the research site is dusty clay loam (25% sand, 46% dust, and 26% clay). Soil pH, neutral (6.67), low C-organic (1.82%), low total N (0.15%), medium C/N (12%), high P_2O_5 (76 mg per 100 g), medium K_2O (38 mg per 100 g), and high CEC value (25.93 me per 100 g) (South Sulawesi Agricultural Technology Research Center, 2021). The soybean cultivation system progresses through various stages, such as the vegetative growth phase, flowering phase, pod formation phase, pod filling phase, and pod ripening phase. The research used three superior varieties with distinctive characteristics, including Detap-1 (high production and resistant to pod splitting), Devon-1 (high production and high isoflavone content), and Derap-1 (high production and tolerant of pod-sucking pests).

The design used was the split plot design. The varieties (PU) used were as follows: (1) Detap-1, (2) Devon-1, and (3) Derap-1, while subplot (AP) is a design of planting method and three replications. Varieties (PU) used were as follows: (1) Detap-1, (2) Devon-1, and (3) Derap-1, while the subplot (AP) is a planting method: (1) farmers transplanting method with a planting distance of 20 cm × 20 cm, (2) method of transplanting double rows (40 cm × 15 cm × 15 cm), and (3) method of transplanting three rows (40 cm × 15 cm × 15 cm × 15 cm). This variety was planted in subplots (AP) in plots measuring 3 m × 5 m with two seeds per planting hole. When planting soybean seeds, no treatment is carried out on the seeds. The fertilizer used in the research was a compound fertilizer with a composition of 15% N, 15% P, and 15% K. The compound fertilizer at a dose of 300 kg ha^{-1} was applied at 15 days after planting the soybean seeds by hammering and inserting them into the planting hole.

2.1 Data collection

Data collected for soybean plants include: plant height, number of branches, pod color, seed shape, seed hilum color, trichome shape, number and length of trichomes on soybean leaves and pods, degree of damage to soybean leaves and pods due to *S. litura* armyworm attack, pod sucking *R. linearis*, and pod borer *E. zinckenella*, 100 seed weight and seed yield.

The damage level of soybean leaves due to *S. litura* attack in the plant age of 35 days after planting (dap), number of branches per plant at 45 dap, plant height in generative phase plant age of 50 dap, pod color, seed shape, seed hilum color, shape trichomes for the generative phase (50 dap), the number and length of trichomes on soybean leaves at 50 dap, and the damage level of soybean pods due to attack by *S. litura* and *E. zinckenella* at 70 dap are observed. Meanwhile, the weight of 100 seeds, pod color, seed shape, seed hilum color, and seed yield were all observed after harvesting the soybeans.

The rate of damage to the leaves is calculated based on the following formula (Apriani et al., 2021):

$$I = \frac{\sum_{i=0}^{z}(n1\,x\,v1)}{Z\,x\,N}x\,100\%$$

I: Intensity of damage
ni: The number of leaves with a v_i scale
N: Number of leaves observed
Z: The higher v_i

Scale value, v_i:
0: no damage on leaves
1: leaf damage >0–20%
3: leaf damage >20–40%
5: leaf damage >40–60%
7: leaf damage >60–80%
9: leaf damage >80–100%

Pod damage rate is calculated based on the formula:

$$I = \frac{a}{a+b}$$

I: Pod damage intensity.
a: Number of pods damaged by legume pests.
b: The number of pods that are not attacked by legume pests.

2.2 Statistical analysis

All observed data were analyzed using ANOVA. The average ratio of leaf damage intensity caused by *S. litura* and the other parameters was tested using the Duncan test probability level of 5%.

3 Results and discussion

3.1 Characteristics and morphological forms of varieties

3.1.1 Seed shape, hilum color, and pod color

As shown in Figure 1, Detap-1, Devon-1, and Derap-1 have a different seed shape. In Indonesia, most of the seeds are oval in shape. The Detap-1 variety has round-shaped seed, Devon-1 has slightly round-shaped seed, and the Derap-1 variety has round-shaped seed (Indonesian Legume and Tuber Crops Research Institute, 2016). Seed shape, hilum color, and pod color are characteristics of soybean that are used to distinguish one variety from another. The shapes of soybean seeds are classified into round, flat, oval, and flat oval (Suhartini et al., 2013).

There are differences in the hilum color between the Detap-1, Devon-1, and Derap-1 varieties. Detap-1 has a yellow hilum, while Devon-1 and Derap-1 have a light brown hilum (Figure 1), which is in accordance with Indonesian Legume and Tuber Crops Research Institute (2016). Yuniarsih (2017) stated the same thing that hilum color is one of the characteristics of soybean seeds, and each variety has a different hilum color.

Similarly, concerning pod color, Figure 1 illustrates that the Detap-1 variety exhibits yellow pods, the Devon-1 variety displays light brown pods, and the Derap-1 variety presents yellow pods. Pod color serves as a distinguishing characteristic for soybeans, commonly used in variety identification. Each variety may share the same pod color or there may be variations (Indonesian Legume and Tuber Crops Research Institute, 2016).

3.1.2 Trichomes form on soybean leaves and pods

Figures 2, 3 show that the soybean varieties, i.e., Detap-1, Devon-1, and Derap-1, have the same shape and type of trichomes, such as the non-granular type. The results showed that each variety had a different shape of trichomes. The difference in the shape of the trichomes is influenced by genetic traits and plant growing environment. Trichomes as a morphological feature of soybean plants have characteristics that can influence the behavior of insect pests. The type of variety affects the diversity and abundance of pests, which also has an impact on the level of leaf damage, pod damage, and overall productivity (Faiz et al., 2021; Aryati and Ulina, 2023). Trichomes are a part of the plant that are above the plant epidermal tissue with various functions. Several previous studies stated the ability of trichomes to protect plants from herbivorous insects (Ebrahimi et al., 2022; Salazar-Mendoza et al., 2023), UV radiation (Rai and Agrawal, 2020; Karabourniotis et al., 2021), pathogens (Kono and Shimizu, 2020), and excessive transpiration (Shahzad et al., 2021), and influence seed protection (Li et al., 2021). This aspect is evidenced by the shape of the ends of the trichomes, which do not form a circle (taper) (Watts and Kariyat, 2022). Granular trichomes differ from non-granular structures because various chemical compounds are secreted, such as sticky exudate from trichomes. This type of trichome has the potential to trap or paralyze insects that cross its path.

Glandular trichomes can also release toxic substances that have many effects on insects, including reducing growth rates and preventing oviposition. In previous studies on wild tomato plants, it was shown that granular trichomes in wild tomatoes (*Solanum habrochaites*) contain sesquiterpene compounds, which have an effect on the performance, feeding habits, and behavior of *Macrosiphum euphorbiae* (Wang et al., 2020; Blanco-Sánchez et al., 2021). In the non-granular type, the trichomes physically function to dispel biotic and abiotic stress levels. Sharp (taper) shape of trichome will prevent herbivorous insect attacks and control the humidity around it (Kariyat et al., 2017; Kaur and Kariyat, 2020).

3.1.3 Length and number of trichomes in soybean leaves and pods

In this study, the primary pests affecting soybeans were identified ad *S. litura*, *R. linearis*, and *E. zinckenella*. The attack of the *S. litura* borer (Table 1) on the Devon-1 variety had the lowest attack compared with Detap-1 and Derap-1. This aspect is different from the attack of the pod borer *E. zinckenella* and *R. linearis*, where Derap 1 has the lowest attack and is significantly different from the other varieties. The difference in attack on these varieties can be caused by several factors. In observing the length of the trichomes and the number, the varieties showed significantly different results. Detap-1 treatment had the longest average trichomes, and Derap 1 had a lower density than the other two varieties, such as 57.27 per

FIGURE 1
Seed shape, hilum color, and pod color for Detap-1, Devon-1, and Derap-1 varieties.

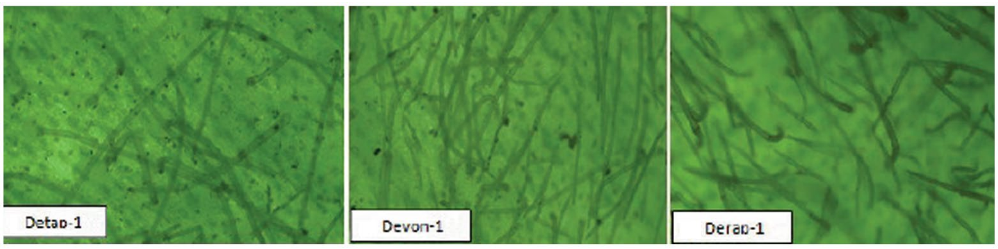

FIGURE 2
Form of trichomes in Detap-1, Derap-1, and Devon-1 leaves.

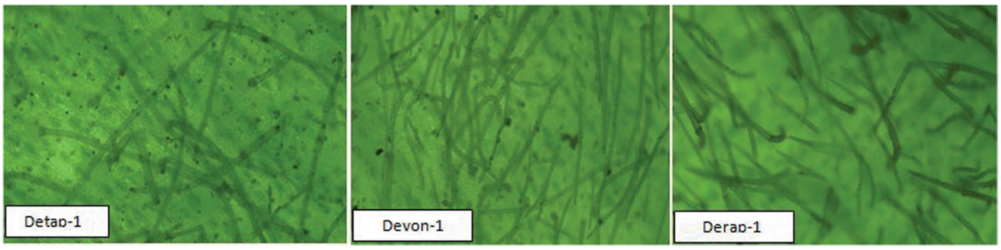

FIGURE 3
Form of trichomes in Detap-1, Derap-1, and Devon-1 soybean pods.

mm^2. *Etiella zinckenella* larvae will grow and develop in soybean plant pods. After hatching into larvae, the larvae will make holes in the pods as a source of food for the larvae (Bayu and Prayogo, 2019; Chi et al., 2019). Nymphs and adults of *R. linearis* are capable of causing damage to the pods by sucking the seed juice in the pods so that the level of damage is high (Aina, 1975; Mawan and Amalia, 2011). The attack on the pods cannot be related to the trichomes on the leaves. Trichomes on the pods provide more accurate information to identify attacks by *E. zinckenella* and *R. linearis*. This aspect is in accordance with previous studies, which calculated the number of trichomes in the pods and stated that the density of trichomes in the pods and the length of the trichomes were different for each cultivar (Adie and Krisnawati, 2017).

3.2 Plant height and number of branches per plant

There is no significant difference in plant height among the three planting designs. The plant size is varied by the number of branches per plant. The highest number of branches is observed in the three rows transplanting design (3.38 branches), whereas the lowest is in the farmers transplanting design (2.76 branches) (Table 1). The study results (Kuntyastuti et al., 2018) also showed that spacing had an effect on plant height, number of branches, and filled pods. Similarly, the results of the study (Agudamu Yoshihira and Shiraiwa, 2016) demonstrated that population density affects the response of branch formation and soybean yields on Hokkaido determinate and United States indeterminate soybean varieties.

Table 1 reveals that the Detap-1 variety exhibited the highest plant height at 52.13 cm, whereas the lowest height was observed in the Derap-1 variety at 45.11 cm. This result is in accordance with Indonesian Legume and Tuber Crops Research Institute (2016), which is mentioned in the Description of Varieties of Soybean Crops. The Detap-1 variety has a plant height of 68.70 cm, while Derap-1 has a plant height of approximately 59.00 cm. Parameter number of branches per plant is one of the factors that determine the high or low productivity of soybeans. In general, the more the number of branches, the higher the productivity. Table 1 reveals that Devon-1 variety had the highest number of branches (3.42 branches) Detap-1 (2.91 branches) and Derap-1 (2.93 branches) varieties had the lowest. This aspect is in contrast with the report of Indonesian Legume and Tuber Crops Research Institute (2016), which is mentioned in the Description of Varieties of Soybean Crops that the Devon-1 variety has approximately 2–3 branches per plant, while Detap-1 has approximately 3–6 branches per plant and Derap-1 has approximately 2–4 branches per plant.

TABLE 1 Average plant height and number of branches per plant at various soybean plant spacings and several soybean varieties.

Planting method	Plant height (cm)	Number of branches per plant
Farmers transplanting method	49.09a	2.76a
Method of transplanting double rows	52.13a	3.13ab
Method of transplanting three rows	47.47a	3.38b
Varieties		
Detap-1	52.13b	2.91a
Devon-1	51.44b	3.42b
Derap-1	45.11a	2.93a

The numbers followed by the same letter in the same column were not significantly different according to Duncan's test at the 0.05 level.

Table 2 indicates no significant interaction between plant height and planting method as well as variety. According to Ayu Rahmasari and Sebayang (2016), this lack of interaction is due to the influence of the density level on the spacing treatment. The insufficient light on the plant causes the shape of the plant to be taller and weaker. This higher form of plants (etiolation) is due to the activity of the growth hormone, such as auxin (Harjadi and Yahya, 2007).

3.3 Types of primary pests found in soybean plantations

Figure 4 shows that several types of pests are common in soybean plants in Indonesia, including South Sulawesi. The armyworm *S. litura* (Figure 4A) is the pest that causes the most damage to soybean leaves in South Sulawesi. According to Marwoto and Suharsono (2008), *S. litura* is a polyphagous pest; hence, it is often found on plants other than soybeans. *Spodoptera litura* is one of the important pests on soybean plants and can attack on the primary host plants causing yield losses of 10–40% (Sundar et al., 2018). *Spodoptera litura* has high reproductive and migratory capacity (Dhaliwal et al., 2010).

Spodoptera litura activity appeared in mid to late August and peaked in mid to late September (Punithavalli et al., 2014). The pest is spread in almost all areas of soybean and horticultural crops in Indonesia. Armyworms have a wide host range (Marwoto and Suharsono, 2008; Fattah and Ilyas, 2016). This polyphagous nature

TABLE 2 Average plant height and number of branches at interaction between plant spacing and soybean varieties.

Planting method	Plant height (cm)			Number of branches per plant		
	Detap-1	Devon-1	Derap-1	Detap-1	Devon-1	Derap-1
Farmers transplanting method	50.93a	52.20a	44.13a	2.33a	3.13a	2.85a
Method of transplanting double rows	52.20a	52.80a	50.33a	2.93b	3.33a	3.80b
Method of transplanting three rows	53.27a	49.33a	40.87a	3.47c	3.80a	3.55b

The numbers followed by the same letter in the same column were not significantly different according to Duncan's test at the 0.05 level.

FIGURE 4
Spodoptera litura F. **(A)**, pod sucker *Riptortus linearis F.* **(B)**, and pod borer *Etiella zinckenella T.* **(C)**.

allows pests to maintain their life cycle in nature throughout the year by obtaining food from other host plants when the primary host plant is not available. According to Fattah et al. (2020), *S. litura* pests can cause damage to soybean leaves approximately 16.24–45.00%.

In addition to the *S. litura* pest that attacks soybean crops in South Sulawesi, *E. zinckenella* is a pod borer pest that causes huge losses to soybean seed yields. Yield losses of soybean caused by pod borers, such as *E. zinckenella* (Figure 4C), are difficult to estimate because they are influenced by genotype susceptibility, control technology used, farmers' socioeconomic conditions, and other environmental conditions (Oliveira et al., 2014). The pod borer is considered to be the most difficult soybean pest to control due to its larval feeding behavior. Larvae spend most of their time in the pods consuming seeds (Apriyanto et al., 2009).

Another pest that causes huge damage to soybean pods in South Sulawesi is the brown ladybug. The farmer gave the name brown ladybug because the adult ladybug has a brownish color. Young ladybugs (nymphs) are similar to black ants (Figure 4B). Both young ladybugs (nymphs) and adult ladybugs both damage soybean pods by sucking up the liquid in the pods while filling the seeds. Apart from attacking soybean pods, brown ladybugs also attack several other legume crops, such as long beans and green beans (Marwoto et al., 2013).

3.4 The level of damage to leaves and pods caused by three primary soybean pests

As shown in Table 3, it is evident that the lowest incidence of *S. litura* infestation occurred in Devon-1 (11.87%), followed by Detap-1 (14.89%) and Derap-1 (15.51%). The lowest attack rates of *R. linearis* and *E. zinckenella* on Derap-1 varieties were 9.07 and 10.01%, respectively, followed by Detap-1 (10.08 and 12.45%) and Devon-1 (12.58 and 13.77%). In Indonesia, the resistance test of soybean varieties to *S. litura* in the unselected test showed an intensity of pest attack of 34–64 and 19–57% in the selected test (Adie et al., 2020).

The results showed that all cropping design had no significant effect on *S. litura* attack, with an attack rate of 13.44–14.21% (Table 4). Meanwhile, the attack rates of *R. linearis* and *E. zinkenella* were significantly different for each cropping design tested. Similarly in *E. zinckenella* attacks, the 20 cm × 20 cm horn jajar planting design had the highest number of insects (12.55%), followed by 2 Legowo (12.18%) and 3 Legowo (11.58%). In general, the attack rates of *S. litura*, *R. linearis*, and *E. zinckenella* were the lowest compared with the other two cropping designs (Table 4). The high migratory and feeding ability of *S. litura* led attacks on soybeans with different varieties and cropping patterns, which was significantly different from one another.

In general, soybeans are planted in rainfed lowland rice fields in Indonesia during the peak of the dry season, from June to October. At this time, the population of pests that attack the pods increases (Krisnawati and Adie, 2019). *Riptortus linearis* is one of the most damaging pod-sucking insects in South Sulawesi, apart from *Nezara viridula* L. (Hemiptera: Pentatomidae) and *Leptocorisa acuta Fabricius* (Hemiptera: Alydidae) (Rahayu et al., 2018).

Table 3 shows that the level of damage to the pod borer on Detap-1 and Derap-1 is lower than that on Devon-1. The number of trichomes in the pods affects soybean resistance to borers. Trichomes also play a role as a factor of soybean resistance to pod borer because trichome density affects the number of *E. zinckenella* eggs laid and the intensity of attack (Sari and Suharsono, 2010; Poniman et al., 2020). As shown in Table 5, the number of trichomes in the Detap-1 and Devon-1 pods was more numerous and significantly different from the number of trichomes in the Derap-1 pods. The more the number of trichomes in the pods, the greater the number of eggs laid, so the higher the intensity of the attack. This aspect is consistent with the study by Susanto and Adjie (2008); the pod borer prefers to lay eggs in soybean pods, which have a higher number of trichomes and are longer. The aforementioned can damage and result in losses

TABLE 3 Average level of leaf damage due to *Spodoptera litura* attack, pod damage due to *Etiella zinckenella* attack, and pod damage rate due to *Riptortus linearis* attack on three spacing design and three soybean varieties.

Planting method	*S. litura* (%)	*E. zinckenella* (%)	*R. linearis* (%)
Farmers transplanting method	14.21a	12.55c	11.54c
Method of transplanting double rows	13.44a	12.18b	10.49b
Method of transplanting three rows	14.11a	11.58a	9.71a
Varieties			
Detap-1	14.89b	12.45b	10.08b
Devon-1	11.87a	13.77c	12.58c
Derap-1	15.51b	10.01a	9.07a

The numbers followed by the same letter in the same column were not significantly different according to Duncan's test at the 0.05 level.

to the larval stage. The characteristic of long trichomes also inhibits the mechanism for borers to attack pods. Conversely, Table 6 shows that the Detap-1 variety has the highest pod trichome length and is significantly different from other varieties, and this factor has an effect on the lower percentage of pod borer attacks compared with Devon-1.

Meanwhile, there was no significant difference in the effect of the length of the trichomes on the leaves against armyworm attacks. Meanwhile the effect of length and number of trichomes on leaves on armyworm attacks is not significantly different. Based on the description of the varieties, Detap-1 and Devon-1 are sensitive to armyworm attack while Derap-1 exhibits partial resistant. Currently, there is no soybean variety that is fully resistant to armyworm (Sundari and Sari, 2015). The frequency of armyworm attacks on soybean leaves is caused by other factors, such as growing season and temperature. The intensity of armyworm attacks is generally high at the end of July or mid-August to October, where generally the temperature increases and the humidity is low (Uge et al., 2021). In Table 4, the results illustrate the evaluation of pod damage levels attributed to *R. linearis* infestation. Derap-1 planted with a 3-row Legowo pattern showed the least damage (8.02%) followed by Derap-1 with a 2-row Legowo planting pattern (9.13%), Detap-1 Legowo pattern 3 rows (9.20%), Detap-1 Legowo pattern 2 rows (9.92%), Derap-1 horn pattern jajar 20 cm × 20 cm (10.05%), Detap-1 horn pattern jajar 20 cm × 20 cm (11.13%), Devon-1 Legowo pattern 3 rows (11.90%), Devon-1 Legowo pattern 2 rows (12.43%), and the highest damage was in Devon-1 horn pattern jajar 20 cm × 20 cm (13.43%) (Table 4). According to the study of Patu et al. (2021), the Detap-1 variety has a thick pod skin of 0.64 mm. The attack rate of *R. linearis* was high in the 20 cm × 20 cm (11.54%) horn soybean cropping design, followed by jajar 2 Legowo (10.49%) and 3 jajar Legowo (9.71%) (Table 4). The morphological characteristics of the thick shell of the pods are strongly related to the intensity of attack by *R. linearis*. The thicker the soybean pod shell, the lower the intensity of attack by pod-sucking pests. Pod trichomes are a part of the defense system against pests, which can inhibit the process of the stylet penetration of pod-sucking pests. Patu et al. (2021) stated that there was a relationship between the length of the pod trichomes and the intensity of the attacks. The longer the pod trichomes, the higher the attack intensity of sucking pests. On the one hand, long trichomes can withstand attack by pod-sucking pests, but on the other hand, long pod borer trichomes are an ideal medium for imago pod borer pests to lay eggs because eggs laid on long trichomes will prevent predators from preying on the eggs, so the percentage of eggs is very high. Similarly, trichomes can be ideal places for some pests to lay their eggs, which are not easily damaged by environmental disturbances.

3.5 The advantages and disadvantages of the three soybean planting design of how to grow soybeans

In Figure 5, it can be observed that among the three soybean planting design tested, the double rows planting design (Figure 5B) and the three rows transplanting design (Figure 5C) result in a more regular appearance of the plant rows and provide empty or open space. This open or empty space or place has many benefits, making it easier for farmers to spray insecticides (pest and disease control) and liquid fertilizer in plants. Apart from that, another benefit is that it is easier for farmers to collect *S. litura* eggs and larvae and other pests. The two design transplanting (Figures 5B,C) is friendly technology. According to Poniman et al. (2020), the environmentally friendly technological innovation is the Legowo planting system using superior varieties. Similarly, as mentioned in the study by Mardian et al. (2019), the Legowo cropping design has a much better population and productivity when compared with the conventional cropping design. One way to control soybean pests in rainfed rice fields is to carry out appropriate cultivation management using pest-resistant varieties (Aryati and Ulina, 2023). The management of spacing is an environmentally friendly technology design that has a positive impact on the environment and the sustainability of plant productivity (Yan et al., 2020; Singh and Krishnaswamy, 2022).

Generally, the soybean planting distance implemented using a 25 cm × 25 cm tiling system. Double spacing (Legowo 2:1) can be done in an effort to increase production because soybean plants require sufficient light. Spacing is one of the cropping systems by adjusting the pattern of spacing between plants in crop cultivation, which includes the distance between rows and rows of each plant (Karokaro et al., 2015). Setting spacing can increase production because it is related to the availability of nutrients, sunlight which affects photosynthesis, and space for plants to grow. Double spacing (Legowo 2:1) is one of the spacing arrangements that is widely applied in Indonesia, especially for food crops, where the arrangement is alternate between two rows of plants, and there is one empty row, which is not planted. The jajar Legowo 2:1 system with 25 cm × 50 cm produces 213,333 rice clumps per plant compared with the 25 cm × 25 cm upland system, which produces 160,000 clumps; in addition to that, a double cropping system (Legowo) makes maintenance processes, such as fertilizing and maintenance, become easier (Ikhwani et al., 2013). Legowo is a method of growing soybeans that maximizes the utilization of sunlight, water, and nutrients. Legowo increases the soybean yield by 17% compared with a single row; hence, it is a recommended technology package using jajar Legowo to obtain higher yields (Haryati et al., 2021).

TABLE 4 Average level of leaf damage due to *Spodoptera litura* attack, pod damage due to *Etiella zinckenella* attack, and pod damage rate due to *Riptortus linearis* attack on interaction between plant spacing design and soybean varieties in South Sulawesi, Indonesia.

Planting method	Level of leaf damage due to *S. litura attack* (%)			Pod damage rate due to *E. zinckenella* attack (%)			Pod damage rate due to *R. linearis* attack (%)		
	Detap-1	Devon-1	Derap-1	Detap-1	Devon-1	Derap-1	Detap-1	Devon-1	Derap-1
Farmers transplanting method	15.13a	12.53a	16.47a	13.18b	12.13b	12.04b	11.13b	13.43c	10.05a
Method of transplanting double rows	14.40b	11.07a	14.87b	14.26c	13.80c	13.24c	9.92b	12.43c	9.13a
Method of transplanting three rows	13.83b	12.00a	15.20b	10.20a	10.36a	9.47a	9.20a	11.90b	8.02a

The numbers followed by the same letter in the same column were not significantly different according to Duncan's test at the 0.05 level.

TABLE 5 Number and length of leaf trichomes on three soybean varieties.

Varieties	Trichomes on soybean leaves		Trichomes on soybean pods	
	Trichome length	Number of trichomes	Trichome length	Number of trichomes
Detap1	27.86a	46.67b	29.11a	212.47a
Devon-1	30.93a	32.20c	26.52b	222.47a
Derap-1	24.81b	56.67a	26.96b	148.40b

The numbers followed by the same letter in the same column were not significantly different according to Duncan's test at the 0.05 level.

TABLE 6 Average 100 seed weight and seed yield per ha of several soybean varieties and various soybean plant spacing.

Varieties	Weight of 100 seeds (g)	Seed yield (t ha $^{-1}$)
Detap-1	17.30b	1.85a
Devon-1	16.33a	1.90a
Derap-1	17.94b	1.91a
Planting method		
Farmers transplanting method	16.92a	1.66a
Method of transplanting double rows	17.27a	1.97b
Method of transplanting three rows	17.38a	2.03b

The numbers followed by the same letter in the same column were not significantly different according to Duncan's test at the 0.05 level.

3.6 Weight of 100 seeds and seed yield t ha^{-1}

The weight of 100 seeds is an indicator of the size of the soybean seeds. The heavier the measurement of 100 soybeans, the larger the size of the soybeans. Table 6 shows that the highest weight of 100 seeds was observed in Derap-1 (17.94 g) and Detap-1 (17.30 g) while the lowest was in Devon-1 (16.33). In accordance with research conducted by the Indonesian Legume and Tuber Crops Research Institute (2016), which is mentioned in the Description of Varieties of Soybean Crops, the weight of 100 seeds for a variety, while Derap-1 is around 17.62 g, Detap-1 is about 15.37 g, and Devon-1 is about 14.30 g.

Soybean seed yield is the main target of farmers in the farming system. Each variety has different seed yields, and this is determined by genes and environmental factors. Based on data from Table 6, it can be observed that there was no significant difference in the seed yields of the three varieties, namely, Detap-1, Devon-1, and Derap-1. According to the report of Indonesian Legume and Tuber Crops Research Institute (2016), which is mentioned in the Description of Varieties of Soybean Crops, the average seed yield of the Detap-1 variety is approximately 2.70 t ha^{-1}, Derap-1 is approximately 2.82 t ha^{-1}, and Devon-1 is approximately 2.75 t ha^{-1}. According to Vlachostergios et al. (2021), the selection of cultivars and planting systems is an important factor for maximizing the yield of soybean seeds. The results of the study (Purwaningrahayu, 2023) showed the variability of the response of each genotype to different planting methods. Based on the productivity per hectare, there are nine accession numbers 2, 3, 5, 6, 8, 9, 11, 13, and 15, which are likely to produce soybean productivity above 3.0 tons/ha, with a double row planting of 50 cm × (30 cm × 15 cm) and more than a single row size of 40 cm × 15 cm.

Table 7 shows that there is no significant difference in the weight of 100 seeds among the three varieties with the three transplanting methods. The lack of significant difference is attributed to the fact that the three tested varieties possess large and nearly identical seed sizes. In Indonesia, soybeans are classified as large (weight > 14 g 100 seeds^{-1}), medium (10–14 g 100 seeds^{-1}), and small (<10 g 100 seeds^{-1}) (Indonesian Legume and Tuber Crops Research Institute, 2016). This classification aligns with the findings by Faizah and Yuliani (2019), which indicates that Detap-1, Devon-1, and Derap-1 varieties have relatively large seed sizes as their weights exceed 14 g 100 seeds^{-1}. One of the things that affects the size of the seeds is the height of the plants. Plant height can lead to a reduction in branches and subsequently affect seed size, as indicated by research results, involving the farmers transplanting method and the method of transplanting double rows with Detap-1, Devon-1, and Derap-1 varieties, in accordance with the findings by Krisnawati (2017). However, the outcomes of the method of transplanting three rows treatment on Detap-1 and Devon-1 varieties did not align with the results presented by Krisnawati (2017). Moreover, the implementation of a dual row spacing measuring 50 cm × (30 cm × 15 cm) has been proven to augment the productivity of soybeans by 11% in comparison with a singular row spacing of 40 cm × 15 cm (Purwaningrahayu, 2023).

FIGURE 5
Farmers transplanting method **(A)**, method of transplanting double rows **(B)**, and method of transplanting three rows **(C)**.

TABLE 7 Average weight of 100 seeds and seed yield at interaction between plant spacing and soybean varieties in South Sulawesi, Indonesia.

Planting method	Weight of 100 seeds (g)			Seed yield (t ha $^{-1}$)		
	Detap-1	Devon-1	Derap-1	Detap-1	Devon-1	Derap-1
Farmers transplanting method	16.97a	15.78a	18.01a	1.67a	1.68a	1.64a
Method of transplanting double rows	17.63a	16.53a	17.98a	1.91b	1.96b	2.03b
Method of transplanting three rows	17.30a	16.68a	17.83a	1.97b	2.08b	2.02b

The numbers followed by the same letter in the same column were not significantly different according to Duncan's test at the 0.05 level.

4 Conclusion

- In the three soybean transplanting design tested, the three rows transplanting design provided the highest seed yield and the lowest level of pod damage due to attacks by the pod borer *E. zinckenella* and the pod sucker *R. linearis*.
- The Derap-1 variety exhibited the highest t ha^{-1} seed yield and the lowest level of pod damage due to attacks by pod borers *E. zinckenella* and *R. linearis*. Meanwhile, Devon-1 responded with the lowest level of damage to soybean leaves due to *S. litura* attack.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

AbF: Writing – original draft, Conceptualization, Formal analysis, Resources. MY: Resources, Conceptualization, Supervision, Writing – original draft. DH: Writing – review & editing, Investigation. MH: Methodology, Writing – original draft. HW: Writing – review & editing, Methodology. EN: Writing – review & editing, Methodology, Software. SS: Writing – review & editing, Investigation. AR: Writing – review & editing. YN: Writing – review & editing, Investigation. EW: Visualization, Writing – original draft. RH: Writing – review & editing. Rohimatun: Writing – review & editing. ASe: Writing – review & editing. Nurhafsah: Writing – review & editing, Methodology. IA: Writing – review & editing, Visualization.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. The authors extend their gratitude to the IAARD, Ministry of Agriculture, Indonesia, for their funding assistance in 2021, as documented by DIPA of the South Sulawesi Province Agricultural Technology Study Center in 2021 number: SP DIPA-018.09.2.634036/2021.

Acknowledgments

The authors thank Ir. Abdul Wahid, MP, Head of the South Sulawesi Province Agricultural Technology Study Center, who has provided land for research and other equipment so that this research can run well.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Adie, M. M., and Krisnawati, A. (2017). Variability of pod trichome and agronomic characters of several soybean genotypes. *Biodiversitas* 18:417–421. doi: 10.13057/biodiv/d180153

Adie, M. M., Krisnawati, A., and Baliadi, Y. (2020). Evaluation for soybean resistance to armyworm *Spodoptera litura* (Lepidoptera: Noctuidae). *IOP Conf. Ser. Earth Environ. Sci.* 484:417–421. doi: 10.1088/1755-1315/484/1/012020

Agudamu Yoshihira, T., and Shiraiwa, T. (2016). Branch development responses to planting density and yield stability in soybean cultivars. *Plant Prod. Sci.* 19, 331–339. doi: 10.1080/1343943X.2016.1157443

Aina, J. O. (1975). The life history of *Riptortus dentipes* F. (Alydidae, Heteroptera) a pest of growing cowpea pods. *J. Nat. Hist.* 9, 589–596. doi: 10.1080/00222937500770471

Aji, A. W., Santoso, S. J., and Siswadi. (2019). Kajian macam jarak tanam terhadap intensitas penyakit bercak daun (Cercospora sojina) pada tiga varietas kedelai (*Glycine max* L. Merrill). *J. Inov. Pertan.* 21, 8–11. doi: 10.33061/innofarm.v21i2.3423

Anderson, E. J., Ali, M. L., Beavis, W. D., Chen, P., Clemente, T. E., Diers, B. W., et al. (2019). "Soybean [*Glycine max* (L.) Merr.] breeding: history, improvement, production and future opportunities" in *Advances in Plant Breeding Strategies: Legumes* (Springer Nature Switzerland AG: Springer International Publishing), 431–516.

Apriani, D., Supeno, B., and Haryanto, H. (2021). "Host preference test for *Spodoptera frugiperda* on several food crops" in *Saintek Proceedings*. Vol 3 (E-ISSN: 2774–8057), 229–236.

Apriyanto, D., Hendra Yoga, O., and Andi, M. (2009). Performance of soybean pod borer, Etiellazinckenella Treitschke (Lepidoptera: Pyralidae), and host preference on soybean and groundnut. *J. Akta Agrosia* 12:62.

Aryati, V., and Ulina, E. S. (2023). Effect of soybean variety and pest management on the sustainable production. *IOP Conf. Ser. Earth Environ. Sci.* 1172:012032. doi: 10.1088/1755-1315/1172/1/012032

Ayu Rahmasari, D., and Sebayang, S. H. T. (2016). The effect of spacing and planting time soybean of growth and yield soybean (*Glycine max*) on sugar cane (*Saccharum officinarum* L.) row. *J. Produk. Tanaman* 4, 392–398.

Bayu, M. S. Y. I., and Prayogo, Y. (2019). Resistance of soybean genotypes with large seed size and early maturity against pod borer, Etiellazinckenella Treitschke. *J. Trop. Plant Pests Dis.* 19, 135–142. doi: 10.23960/j.hptt.219135-142

Bhatt, P., Singh, K. P., and Aravind, T. (2022). Screening of soybean varieties under natural epiphytotic conditions against anthracnose/pod blight (Colletotrichum truncatum (Schw.) Andrus and Moore). *Indian Phytopathol.* 75, 1185–1189. doi: 10.1007/s42360-022-00541-5

Blanco-Sánchez, L., Planelló, R., Llorente, L., Díaz-Pendón, J. A., Ferrero, V., Fernández-Muñoz, R., et al. (2021). Characterization of the detrimental effects of type IV glandular trichomes on the aphid *Macrosiphum euphorbiae* in tomato. *Pest Manag. Sci.* 77, 4117–4127. doi: 10.1002/ps.6437

Chen, Z., Zhang, C., Du, H., Chen, C., Xue, Q., and Hu, Y. (2022). Effect of starter cultures on dynamics succession of microbial communities, physicochemical parameters, enzyme activities, tastes and volatile flavor compounds during sufu fermentation. *Food Chem. Adv.* 1:100057. doi: 10.1016/j.focha.2022.100057

Chi, J., Liu, J., Chen, P., Liu, J., and Liu, Y. (2019). Best conditions for rearing Etiellazinckenella (Treitschke). *Chin. J. Appl. Entomol.* 56, 595–598.

Dhaliwal, G. S., Jindal, V., and Dhawan, A. K. (2010). Insect Pest problems and crop losses: changing trends. *Ind. J. Ecol.* 37, 1–7. doi: 10.13140/RG.2.2.25753.47201

Direktorat Jendral Tanaman Pangan (Dirjentan) (2019). *LaporanKinerja*. Jakarta: Ministry of Agriculture Indonesia.

Ebrahimi, L., Golmohammadi, G., and Shiri, M. (2022). Trichome density and pod damage rate as the key factors affecting soybean yield under natural infestation of Helicover paarmigera (Hübner). *J. Plant Dis. Protect.* 129, 955–966. doi: 10.1007/s41348-022-00587-7

Elisa Faizaty, N., Rifin, A., and Tinaprilla, N. (2016). Proses Pengambilan Keputusan Adopsi Inovasi Teknologi Budidaya Kedelai Jenuh Air (Kasus: Labuhan Ratu Enam, Lampung Timur). *J. Agribus. Rural Dev. Res.* 2, 97–106. doi: 10.18196/agr.2230

Faiz, M. F., Hidayat, P., Winasa, I. W., and Guntoro, D. (2021). Effect of soybean leaf trichomes on the preference of various soybean pests on field. *IOP Conf. Ser. Earth Environ. Sci.* 694:012046. doi: 10.1088/1755-1315/694/1/012046

Faizah, M., and Yuliani, A. I. (2019). *Manfaat Biofertilizer dan Micoriza Tanaman Kedelai* Google Book.

Fattah, A, and Ilyas, A (2016). "Siklus hidup ulat grayak (Spodoptera litura F) dan tingkat serangan pada beberapa varietas unggul kedelai di Sulawesi Selatan" in *Prosiding Seminar Nasional Inovasi Teknologi Pertanian*. Banjarbaru.

Fattah, A., Sjam, S., Daud, I. D., Dewi, V. S., and Ilyas, A. (2020). Impact of armyworm spodopteralitura (Lepidoptera: Noctuidae) attack: Damage and loss of yield of three soybean varieties in South Sulawesi, Indonesia. *J Crop Prot* 9, 483–495.

Fattah, A., Syam, S., Daud, I. D., Sartika Dewi, V., and Rahman, A. (2018). The intensity of leaf damage caused by attack of *Spodoptera litura* F and seed yield on some soybean varieties in South Sulawesi Indonesia. *Sci. Res. J.* VI:55.

Gulluoglu, L., Bakal, H., Sabagh, A. E. L., and Arioglu, H. (2017). Soybean managıng for maxımıze productıon: plant population densıty effects on seed yıeld and some agronomical traıtsınmaın cropped soybean productıon. *J. Exper. Biol. Agri. Sci.* 5, 31–37. doi: 10.18006/2017.5(1).031.037

Han, S. S., Park, H. J., Shin, T., Ko, J., Choi, W. J., Lee, Y. H., et al. (2022). Effects of tillage system, sowing date, and weather course on yield of double-crop soybeans cultivated in drained Paddy fields. *Agronomy* 12:1–17. doi: 10.3390/agronomy12081901

Harjadi, S. S., and Yahya, S. (2007). *Fisiologi Stres Lingkungan*. Bogor: Pau Bioteknologi IPB-Press.

Harsono, A., Sarjia, H.A., and Santoso, A. (2012). Kajian keefektifan pupuk hayati pada kedelai dilahan masam dan non masam.

Haryati, Y., Sari, R., Noviana, I., and Sunandar, N. (2021). Adaptive technology for soybean varieties cultivation in dry season. *IOP Conf. Ser. Earth Environ. Sci.* doi: 10.1088/1755-1315/648/1/012067

Ikhwani, J., Pratiwi, G. R., Paturrohman, E., and Makarim, A. K. (2013). Peningkatan Produktivitas Padi Melalui Penerapan Jarak Tanam Jajar Legowo. *IPTEK Tanaman Pangan* 8, 72–79.

Indonesian Legume and Tuber Crops Research Institute (2016). Description of legume and tuber crops seeds. Central Research Institute for Food Crops—The AARD, The Ministry of Agriculture of Indonesia.

Karabourniotis, G., Liakopoulos, G., Bresta, P., and Nikolopoulos, D. (2021). The optical properties of leaf structural elements and their contribution to photosynthetic performance and photoprotection. *Plan. Theory* 10:1–18. doi: 10.3390/plants10071455

Kariyat, R. R., Smith, J. D., Stephenson, A. G., De Moraes, C. M., and Mescher, M. C. (2017). Non-glandular trichomes of *Solanum carolinense* deter feeding by manducasexta caterpillars and cause damage to the gut peritrophic matrix. *Proc. R. Soc. B Biol. Sci.* 284:1–9. doi: 10.1098/rspb.2016.2323

Karokaro, S., Rogi, J. E. X., Runtunuwu, D. S., and Tumewu, P. (2015). Setting distance planting Rice (*Oryza sativa* l.) on the system Jajar Legowo. *J. Ilmiah Fakult. Pertan. Univ. Sam Ratul.* 6, 1–7.

Kasno, A., Rostaman, T., Diah, D., Balai, S., Tanah, P., TentaraPelajar, J., et al. (2016). Increasing productivity of Rainfed area with N, P, and K Fertlizers and use of high yielding varieties. *J. Tanah Iklim* 40, 147–157.

Kaur, I., and Kariyat, R. R. (2020). Eating barbed wire: direct and indirect defensive roles of non-glandular trichomes. *Plant Cell Environ.* 43, 2015–2018. doi: 10.1111/pce.13828

Kezar, S., Ballagh, A., Kankarla, V., Sharma, S., Sharry, R., and Lofton, J. (2023). Response of soybean yield and certain growth parameters to simulated reproductive structure removal. *Agronomy* 13:1–17. doi: 10.3390/agronomy13030927

Khan, M. A., Sahile, A. A., Jan, R., Asaf, S., Hamayun, M., Imran, M., et al. (2021). Halotolerant bacteria mitigate the effects of salinity stress on soybean growth by regulating secondary metabolites and molecular responses. *BMC Plant Biol.* 21:176. doi: 10.1186/s12870-021-02937-3

Kharisma, B. (2018). Determinan Produksi Kedelai di Indonesia dan Implikasi Kebijakannya. *E-J. Ekon. Bisnis Univ. Uday.* 7, 679–710. doi: 10.24843/EEB.2018.v07.i03.p03

Kono, A., and Shimizu, T. (2020). Leaf Trichomes as an effective structure for disease resistance: the case of grapevine downy mildew. *Jpn. Agric. Res. Q.* 54, 293–298. doi: 10.6090/jarq.54.293

Krisnawati, A. (2017). Kedelai sebagai Sumber Pangan Fungsional. *Iptek Tanaman Pangan* 12, 57–65.

Krisnawati, A., and Adie, M. M. (2019). The resistance of soybean genotypes to the pod feeding insects. *Planta Trop. J Agro Sci.* 7:48–57. doi: 10.18196/pt.2019.093.48-57

Kuntyastuti, H., Lestari, S. A. D., and Sutrisno, S. (2018). Effects of organic fertilizer and plant spacing on early-medium maturity soybean. *J. Degrad. Mining Lands Manag.* 5, 1171–1179. doi: 10.15243/jdmlm.2018.053.1171

Li, J., Tang, B., Li, Y., Li, C., Guo, M., Chen, H., et al. (2021). Rice SPL10 positively regulates trichome development through expression of HL6 and auxin-related genes. *J. Integr. Plant Biol.* 63, 1521–1537. doi: 10.1111/jipb.13140

Mardian, I., Hipi, A., and Widyastuti, E. (2019). Produktivitas dan Pendapatan Sistem Usaha Tani Kedelai dengan Berbagai Sistem Jajar Legowo. *J. Penelit. Tanam. Pangan* 3:153–153.

Maros Regency Central Statistics Agency (2022). Observation of climate elements by Monts at climatology 1, Maros.

Marwoto, Hardaningsih, S, and Taufiq, A (2013). *Hama, penyakit, dan masalah hara pada tanaman kedelai*. Bogor: Badan Penelitian dan Pengembangan Pertanian, Pusat Penelitiandan Pengembangan Tanaman Pangan

Marwoto, and Suharsono, (2008). Strategi dan komponen teknologi pengendalian ulat grayak (Spodopteralitura Fabricius) pada tanaman kedelai. *J. Litbang Pertan.* 27, 131–136.

Mawan, A., and Amalia, H. (2011). Statistika Demografi Riptortuslinearis F. (Hemiptera: Alydidae) padaKacangPanjang (Vignasinensis L.). *J. Entomol. Indonesia* 8, 8–16. doi: 10.5994/jei.8.1.8

Musser, F. R., Catchot, A. L., Conley, S. P., Davis, J. A., Difonzo, C., Greene, J. K., et al. (2020). 2019 Soybean Insect Losses in the United States. 17. Available at: www.midsouthentomologist.org.msstate.edu

Nurbaiti, F., Haryono, G., and Suprapto, A. (2017). Pengaruh Pemberian Mulsa dan Jarak Tanam pada HasiI TanamanKedelai (*Glycine max*, L. Merrill.) Var. Grobogan. *J. Ilmu Pertan. Trop. Subtrop.* 2, 41–47.

Oliveira, C. M., Auad, A. M., Mendes, S. M., and Frizzas, M. R. (2014). Crop losses and the economic impact of insect pests on Brazilian agriculture. *Crop Prot.* 56, 50–54. doi: 10.1016/j.cropro.2013.10.022

Otie, V., Udo, I., Shao, Y., Itam, M. O., Okamoto, H., An, P., et al. (2021). Salinity effects on morpho-physiological and yield traits of soybean (Glycine max l.) as mediated by foliar spray with brassinolide. *Plan. Theory* 10, 1–24. doi: 10.3390/plants10030541

Patu, B. A., Sarjan, M., Tarmizi, and Tantawizal. (2021). The relationship of the morphological characteristics of some varieties of soybean on the attack itensity of the pod borer (Etiellazinckenella Treitschke) in two different cultivation techniques. *IOP Conf. Ser. Earth Environ. Sci.* 913:012013. doi: 10.1088/1755-1315/913/1/012013

Poniman, C., Sunardi, T., and Pujiwati, H. (2020). Serangan Hama Penggerek Polong Pada Enam Varietas Kedelai Dan Pengaruhnya Terhadap Hasil. *J. Ilmu-Ilmu Pertan. Indonesia* 22, 38–44. doi: 10.31186/jipi.22.1.38-44

Prince, S. J., Vuong, T. D., Wu, X., Bai, Y., Lu, F., Kumpatla, S. P., et al. (2020). Mapping quantitative trait loci for soybean seedling shoot and root architecture traits in an inter-specific genetic population. *Front. Plant Sci.* 11:1284. doi: 10.3389/fpls.2020.01284

Punithavalli, M., Sharma, A. N., and Rajkumar, M. B. (2014). Seasonality of the common cutworm *Spodoptera litura* in a soybean ecosystem. *Phytoparasitica* 42, 213–222. doi: 10.1007/s12600-013-0354-5

Purwaningrahayu, R. D. (2023). "High yield potential of fifteen soybean accessions with different planting methods" in *AIP Conference Proceedings*. England: IOP Publishing Ltd. 2583, 020005 (2023).

Pusat Pengkajian Perdagangan Dalam Negeri (PPPDN) (2019). *Analisis Perkembangan Harga Bahan Pangan Pokok di Pasar Domestik dan Internasional*. Jakarta Ministri of Trade Indonesia.

Rahayu, M., Bande, L. O. S., Hasan, A., Yuswana, A., and Rinambo, F. (2018). Contribution of pod borer pests to soybean crop production (case in Pondidaha, Konawe District, Southeast Sulawesi). *IOP Conf. Ser. Earth Environ. Sci.* 122:12039. doi: 10.1088/1755-1315/122/1/012039

Rai, K., and Agrawal, S. B. (2020). Effect on essential oil components and wedelolactone content of a medicinal plant *Eclipta alba* due to modifications in the growth and morphology under different exposures of ultraviolet-B. *Physiol. Mol. Biol. Plants* 26, 773–792. doi: 10.1007/s12298-020-00780-8

Rasyd, H. (2013). Peningkatan Produksi Dan Mutu Benih Kedelai Varietas Hitam Unggul Nasional Sebagai Fungsi Jarak Tanam Dan Pemberian Dosis Pupuk P. *J. Gamma* 8, 46–63.

Salazar-Mendoza, P., Magalhães, D. M., Lourenção, A. L., and Bento, J. M. S. (2023). Differential defensive and nutritional traits among cultivated tomato and its wild relatives shape their interactions with a specialist herbivore. *Planta* 257:76. doi: 10.1007/s00425-023-04108-0

Santoso, S. J., Siswadi, and Istiana, E. (2020). Study of type of planting distance on three soybean varieties to the intensity of pest and pathogen attacks. *J. Res. Fair Unisri* 4, 95–106.

Sari, K. P., and Suharsono. (2010). Trikoma sebagai factor ketahanan kedelai terhadap hama penggerek polong. *Bulet. Palaw.* 20, 80–83.

Sarkodie-Addo, J., and Mahama, O. (2012). Growth and yield response of early and medium maturity soybean (*Glycine max* (L) Merrill) varieties to row spacing. *Int. J. Sci. Adv. Technol.* 2: 115–122.

Shahzad, M., Khan, Z., Nazeer, W., Arshad, S. F., and Ahmad, F. (2021). Effect of drought on Trichome density and length in cotton (*Gossypium Hirsutum*). *J. Biores. Manag.* 8, 154–167. doi: 10.35691/jbm.1202.0174

Singh, P., and Krishnaswamy, K. (2022). Sustainable zero-waste processing system for soybeans and soy by-product valorization. *Trends Food Sci. Technol.* 128, 331–344. doi: 10.1016/j.tifs.2022.08.015

South Sulawesi Agricultural Technology Research Center (2021). Report on soil test results in Maros regency. Center for the Study and Development of agricultural technology. Agricultural Research and Development Agency. Ministry of Agriculture.

Srihartanto, E., Anshori, A., and Iswadi, A. (2015). "Produktivitas kedelai dengan berbagai jarak tanam di Yogyakarta" in *Prosiding Seminar Hasil Penelitian Tanaman Aneka Kacang dan Umbi*, 151–154

Subandi, and Anwari, (2012). Pembinaan penangkar benih kedelai di Sulawesi Selatan.

Sundar, B., Rashmi, V., Sumith, H. K., and Sandhya, S. (2018). Study the incidence and period of activity of *Spodoptera litura* on soybean. *J. Entomol. Zool. Stud.* 6:331–333.

Sundari, T., and Sari, K. P. (2015). Perbaikan Ketahanan Kedelai terhadap Hama Ulat Grayak (Improvement of Soybean Resistant to Armyworm). *Iptek Tanaman Pangan* 10, 19–28.

Suhartini, P., Aufiq, A., and Nugrahaeni, N. (2013). Karakteristik Tanaman Kedelai. Panduan *Roguing Tanaman dan Pemeriksaan Benih Kedelai*. Pusat Penelitian Tanaman Pangan Bogo.

Supriono, (2000). Pengaruh dosis urea tablet dan jarak tanam terhadap pertumbuhan dan hasil kedelai Kultivar Sindoro. *Agrosains* 2, 64–71.

Susanto, G. W. A., and Adjie, M. M. (2008). Penciri Ketahanan Morfologi Genotipe Kedelai Terhadap Hama Penggerek Polong. *J. Penelit. Pertan. Tanam. Pangan* 27, 95–100.

Syafruddin, I., Sulukpadang, and Saidah, (2014). "Keragaan tiga varietas unggul baru kedelai dan kelayakan usaha tani di Kab. Parigi Moutong Sulawesi Tengah" in *Prosiding Seminar Hasil Penelitian Tanaman Aneka Kacang dan Umbi 2014*.

Tetila, E. C., Machado, B. B., Astolfi, G., Belete, N. A. D. S., Amorim, W. P., Roel, A. R., et al. (2020). Detection and classification of soybean pests using deep learning with UAV images. *Comput. Electron. Agric.* 179:105836. doi: 10.1016/j.compag.2020.105836

Uge, E., Yusnawan, E., and Baliadi, Y. (2021). Environmentally friendly control of armyworms (*Spodoptera litura* Fabricius) on soybean. *Bulet. Palaw.* 19, 64–80.

Vlachostergios, D. N., Noulas, C., Baxevanos, D., Raptopoulou, C. G., Aggelopoulos, V., Karanika, C., et al. (2021). Response of early maturity soybean cultivars to row spacing in full-season crop and double-crop systems. *Plant Soil Environ.* 67, 18–25. doi: 10.17221/433/2020-PSE

Wang, F., Park, Y. L., and Gutensohn, M. (2020). Glandular trichome-derived sesquiterpenes of wild tomato accessions (*Solanum habrochaites*) affect aphid performance and feeding behavior. *Phytochemistry* 180:112532. doi: 10.1016/j.phytochem.2020.112532

Watts, S., and Kariyat, R. (2022). Morphological characterization of trichomes shows enormous variation in shape, density and dimensions across the leaves of 14 Solanum species. *AoB Plants* 13:1–31. doi: 10.1093/aobpla/plab071

Yan, S., Ren, B., Zeng, B., and Shen, J. (2020). Improving RNAi efficiency for pest control in crop species. *BioTechniques* 68, 283–290. doi: 10.2144/BTN-2019-0171

Yuniarsih, D. (2017). "Pengaruhcekaman air terhadapkandungan protein kacangkedelai" in *Prosiding Seminar Nasional Pendidikan Biologi dan BiologiJurusan Pendidikan Biologi, Fakultas MIPA*. Universitas Negeri Yogyakarta.

Zhao, M., Ren, Y., Wei, W., Yang, J., Zhong, Q., and Li, Z. (2021). Metabolite analysis of Jerusalem artichoke (*Helianthus tuberosus* l.) seedlings in response to polyethylene glycol-simulated drought stress. *Int. J. Mol. Sci.* 22:1–15. doi: 10.3390/ijms22073294