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Characteristics of several soybean varieties (*Glycine max* L.) and weed management systems in an effort to increase productivity in low land rice

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Soybean productivity in paddy fields is influenced by variety selection and grass management practices. This study aimed to assess several soybean varieties and evaluate the impact of soil processing and weed control on Summed Dominance Ratio (SDR), as well as growth and yield of soybean seeds. Conducted in Sungai Kakap, Kubu Raya, West Kalimantan, during 2021, the research employed a Randomized Block Design with 15 treatments and 3 replications. Treatments included various combinations of tillage methods, weed control techniques, and mulching. The study identified four soybean varieties Detap-1, Derap-1, Devon-1, and Dena-2 with large seed sizes and high yields. These varieties also exhibited resistance to common pests such as *Etiella zinkenella*, *Riptortus linearis*, and *Spodoptera litura*. Weed composition analysis revealed *O. sativa* and *Ageratum conyzoides* as dominant species. Weed dry weight was lowest in the perfect tillage + pre-emergence herbicide treatment and highest in the minimum tillage + weeds are not controlled treatment. The highest plant growth and seed yield were observed in the minimum tillage + pre-emergence herbicide and perfect tillage + pre-emergence herbicide treatments. Plant height, number of pods per plant, number of seeds per plant, and dry seed yield were significantly higher in these treatments compared to others. In conclusion, varieties Detap-1, Derap-1, Devon-1, and Dena-2 possess suitable physical characteristics for cultivation in Indonesia. The most effective grass management models identified were minimum tillage + pre-emergence herbicide and perfect tillage + pre-emergence herbicide. These findings contribute to optimizing soybean cultivation practices, emphasizing varietal selection and weed control strategies for improved crop performance.

KEYWORDS

soybean, characteristics, weed, management, system, seed yield

1 Introduction

The soybean plant (*Glycine max L.*) is one of the secondary crops which is very important as food and animal feed. As a food ingredient, soybeans are a source of vegetable protein that is widely consumed by people in Indonesia because the price is cheaper than animal protein (Messina Mark, 1999). Apart from that, soybean seeds are also used as animal feed, especially poultry and dairy cattle (Flemming, 2004; Tallentire et al., 2018; Kartikasari et al., 2019). The productivity of soybean plants in Indonesia is still very low compared to other soybean producing countries such as the United States and Brazil (Indonesia's National Statistical Agency, 2016). The difference in soybean productivity is influenced by several factors, including environmental factors and soybean cultivation management techniques (Nelson and Frederico, 2004; Rusu et al., 2014; Phélinas and Choumert, 2017). Soybeans, which are classified as C3 plants, have strong adaptation to hot and humid conditions in tropical and sub-tropical areas (Seid Tehulie et al., 2021). Management factors that influence soybean yields are conventional soybean cultivation techniques such as the type of variety planted, soil processing system, fertilization, weed control, pest and disease management. Apart from that, the type and characteristics of the varieties planted by farmers greatly determine the level of productivity achieved, because each variety has different characteristics and responses to soil types, weeds, pests and diseases (Fattah et al., 2020; Du et al., 2024). Stated that there are 3 varieties that are widely developed in Indonesia, namely Anjasmoro, Argomulyo, and Grobogan, which have different responses to the level of leaf damage due to *S. litura* attacks, namely Anjasmoro has a leaf damage level of 30.67%, Agromulyo (26.17%) and Grobogan (23.95%).

Conventional soybean cultivation techniques provide opportunities for weeds to compete with soybean plants. The occurrence of competition between weeds and soybean plants for nutrients, water and sunlight causes low soybean yields both in quality and quantity. The competitiveness of weeds with soybeans depends on germination time. If soybean plants germinate faster than weeds, weed growth will be inhibited and competition will be reduced (Datta et al., 2017). Decrease in soybean yield due to competition with various weeds. Soybean yields decrease by 8–55% if weed control is not carried out (Radosevich et al., 2007). Soybean yields decreased by 73.9% due to competition from the dominant weeds *C. dactylon*, *C. rotundus*, and *A. sessilis* compared to weed-free soybean yields during the growth period (Van Acker et al., 1993). The reduction in soybean yield in systems without weed control and loss of seed yield due to grass competition is around 30–80% (Moenandir and Kujaeni, 1990; Berca, 2004). The dominant types of weeds in the soybean cultivation system in paddy fields are grasses (51%), broadleaf weeds (46%), and puzzle weeds (3%). The main weed with narrow leaves is tuton (*Echinochloa colona*), and the main weed with broad leaves is walik ope (*Trianthema portulacastrum*) (Avola et al., 2008).

The application of tillage aims to improve the physical properties of the soil which can increase the growth of soybean plants and suppress the growth of certain weeds, but indirectly tillage can also trigger the emergence of weed seeds from the lower layers to the surface of the soil and weeds. The seeds will grow soon (Arifin et al., 2013). Minimum tillage can increase plant height by 8.78% and pod weight by 32.13% compared to no tillage and maximum tillage (He et al., 2019). Furthermore, Prayogo et al. (2017) stated that planting soybeans in paddy fields after rice does not require tillage because it is inefficient and does not increase crop yields.

The use of rice straw mulch can directly increase soil fertility from the decomposition of rice straw mulch by soil microbes. Apart from that, the use of rice straw mulch can also inhibit the loss of ground water due to evaporation and suppress weed growth (Adisarwanto et al., 2007). Manual weed control using simple tools gives good results but requires a lot of human resources. The use of herbicides is expected to replace human labor, especially in areas that lack human labor (Wiese et al., 2016; Ratnayake et al., 2018).

This research aims to determine: (1) the characteristics of several soybean varieties in Indonesia, (2) the influence of soil processing and weed control on the SDR and dry weight of weeds and (3) the influence of weeds on the growth and seed yield of soybean plants.

2 Materials and methods

This research was carried out from February to June 2021 in rice fields after harvesting rice on farmers' land, Parit Gadu Village, Sungai Kakap District, Kubu Raya Regency, West Kalimantan. The climate conditions and soil type at the research location are around an average temperature and humidity of 26.80°C and humidity of 84%, while the soil type is classified as Alluvial soil (Redhead et al., 2019). The design used in the research was a Randomized Block Design (RAK) with 15 treatments and 3 replications. Treatments tested: (1) No tillage + weeds are not controlled, (2) No tillage +1 time weeding, (3) No tillage +2 times weeding, (4) No tillage+rice straw mulch, (5) No tillage+ pre-emergence herbicide, (6) Minimum tillage + weeds are not controlled, (7) Minimum tillage+1 time weeding, (8), Minimum tillage+2 times weeding, (9) Minimum tillage+ rice straw mulch, (10) Minimum tillage+pre-emergence herbicide, (11) Perfect tillage+weeds are not controlled, (12) Perfect tillage+1 time weeding, (13) Perfect tillage+2 times weeding, (14) Perfect tillage+rice straw mulch, and (15) Perfect tillage+pre-emergence herbicide.

The soybean variety planted is Wilis in a plot measuring 3.2 m × 2.8 m with a spacing of 20 cm × 20 cm and 2 seeds per planting hole. Soybean planting is done using a tool made of wood. Fertilization is carried out twice, first before planting and second at the age of the plant 25 days after planting. The dosage and type of fertilizer used is 90 kg ha^{-1} nitrogen (N), 54.90 kg ha^{-1} phosphate (P), and 18.5 kg ha^{-1} potassium (K). The first fertilization is carried out before planting with a dose of 67.5 kg ha^{-1} nitrogen (N), 54.90 kg ha^{-1} phosphate (P), and 18.5 kg ha^{-1} potassium (K). Meanwhile, the second stage of fertilization is carried out at the age of the plants 25 days after planting with a dose of 22.5 kg ha^{-1} nitrogen (N).

2.1 Parameters observed in this study

Observations on soybean weeds were carried out using the quadratic method and started at plant age 14 days after planting until harvest. The parameters observed were Summed Dominance Ratio (SDR), and dry weight of weeds using a method guided by the weed identification book (The Central Statistics Agency of Kubu Raya Regency, 2021). Other parameters observed in the vegetative phase of the plant were plant height, number of leaves, leaf area, and dry weight of stover, while in the generative phase of the plant the parameters observed were the number of flowers per plant, number of pods per plant, number of seeds per plant, weight of 100 seeds., seed dry weight, and seed yield. Leaf area measurements are carried out using the Leaf Area Meter measuring instrument. Leaf area measurements were carried out at 14, 28, 42, 56, 70, and 80 days after planting.

2.2 Statistical analysis

All observed data were analyzed using variance analysis (ANOVA). The average ration of weed dry weight, plant height, number of leaves per plant, leaf area per plant and the other parameters were tested using the LSD test probability level of 5%. To find out the relationship between independent and dependent variables, correlation analysis, path analysis, and stratified regression analysis was used (Moody, 1981).

3 Results and discussion

3.1 Morphological physical characteristics and response of several soybean varieties to pest and disease attacks

Morphological characters are characteristic of each soybean variety. In Table 1, the plant height of each variety varies with a range of 52–68 cm, the number of branches is 1–6 branches, the leaf shape varies from round to oval, the number of pods per plant is 27–46 seeds and the seed size is from normal to large. These differences in morphological characters are influenced by differences in varieties (Corassa et al., 2019; Huang et al., 2023). Each variety has phenotypic characteristics which are influenced by genetic variation and heritability (Shilpashree et al., 2021). This phenomenon also occurs in response to the presence of pests and diseases. There are 4 soybean varieties tested for resistance to the pest *E. zinkenella* and 1 variety is susceptible. There are 6 soybean varieties tested for resistance to the pest *R. linearis* and only 1 variety has a susceptible response. There are 2 resistant varieties of *S. litura* and 4 varieties that are susceptible. Eight varieties were resistant to Phakopsora pahirhyzi Syd leaf rust disease and 1 variety was moderate (Table 2). Each variety has a different resistance response to the presence of pests and diseases. Differences in response are influenced by variety and environmental factors (Pujiwati et al., 2021; Bueno et al., 2023). The influence of genetic factors and the growing environment supports plant health and is expressed as optimizing plant strength, repairing damaged tissue, stem strength and its ability to produce alternative branches to maintain production (Ginting et al., 2022). The availability and balance of the macro nutrients nitrogen, phosphorus and potassium optimizes the potential for plant defense responses to attacking pests (Pujiwati et al., 2021; Ginting et al., 2022). The availability of macro elements optimizes the expression of physical, chemical and biological plant defense responses (Hu et al., 2022; Liu et al., 2023). Morphology varies, such as leaf surface shape, trichome density, wax layer thickness, stem structural strength and its ability to produce proteins related to plant defense (War et al., 2012; Faiz et al., 2021; Yadav and Singh, 2024). Produces secondary metabolic compounds that are produced under unusual conditions through the biosynthesis of phenylpropanoids, lignin, anthocyanins, dihydroflavanols, schimic acid pathways, cell wall proteins, and signaling cascades (Yang et al., 2023). Other effects can occur due to an induction process by the pest which causes minimal damage after the resistance response occurs (Yadav and Singh, 2024). Apart from that, the interaction of each variety with endophytic microbes and natural enemies of pests will have a significant impact on the growth response and safe defense from pest attacks. This response is genetically induced, so that the plant can produce defense proteins. Induced resistance is utilized to result from the potential of plant types with variations in fast or slow response with endophytic microbes and natural enemies of pests will have a significant impact on the growth response and safe defense from pest attacks. This response is genetically induced, so that the plant can produce defense proteins. Induced resistance is utilized to result from the potential of plant types with variations in fast or slow response (War et al., 2012; Bueno et al., 2023).

In Table 2, the highest seed yields were for the varieties Detap-1, Demas-2, and Derap-1, respectively, 2.70–3.50, 2.39–3.27, and 2.70–3.58 t ha^{-1}. The high seed yield in the three varieties is supported by the high plant height in the three varieties, namely 68.70, 58.1, and 59 cm, respectively. According to Puja Santana et al. (2020), the characteristics of soybean plant height and seed size are parts that influence the yield of soybean seeds per hectare. The number of pods

TABLE 1 Plant height, number of branches, leaf shape, pod color, number of pods, and hilum color in several soybean varieties in Indonesia.

Soybean varieties	Plant height	Number of branches	Leaf shape	Pod color	Number of pods	Weight of 100 seeds	Seed size
Derap-1	± 59	2–4	Round	Yellow	±45	17.62	Big
Deja-1	±52.7	3	Oval	Dark brown	±36	12.90	Currently
Dena-2	± 40.0	1–3	Triangle	Chocolate Yellowish-	±27	13.00	Currently
Dena-1	± 59	1–3	Oval	Brown	±29	14.30	Big
Devon-1	± 58.1	2–3	A bit round	Light brown	± 29	14.3	Big
Dega-1	± 53	1–3	Oval	Light brown	± 29	22.98	Very Big
Deja-2	± 52.3	3	Oval	Dark brown	±38	14.80	Big
Demas-2	± 58.1	2–3	A bit round	Light brown	±29	14.99	Big
Detap-1	±68.70	3–6	A bit round	Yellow	±51	15.37	Big

Description of soybean varieties 2016–2018 (Fattah et al., 2023a).

TABLE 2 Response to soybean pests, response to soybean disease, and potential seed yield.

Soybean varieties	Response to soybean pests	Response to soybean disease	Seed yield (t ha^{-1})
Derap-1	Resistant to attacks by *E. zinkenella* and *R. linearis*	Resistant to *Phakopsora pachirhyzi* Syd leaf rust disease	2.70–3.58
Deja-1	Resistant to attacks by *E. zinkenella, S. litura* and *R. linearis*	Resistant to *Phakopsora pachirhyzi* Syd leaf rust disease	2.39–2.70
Dena-2	Resistant to *R. linearis* and somewhat resistant to *S. litura*	Resistant to *Phakopsora pachirhyzi* Syd leaf rust disease	2.8
Dena-1	Susceptible to pest attacks *R. Linearis* and *S. litura*	Resistant to *Phakopsora pachirhyzi* Syd leaf rust disease	1.70–2.90
Devon-1	Resistant to attacks by *R. linearis and* susceptible to pest attacks *S. litura*	Resistant to *Phakopsora pachirhyzi* Syd leaf rust disease	2.20–2.90
Dega-1	Susceptible to pest attacks *S. litura*	Moderat Resistant to *Phakopsora pachirhyzi* Syd leaf rust disease	2.78–3.82
Deja-2	Susceptible to pest attacks *S. litura,* Resistant to attacks by *E. zinkenella* and *R. linearis*	Resistant to *Phakopsora pachirhyzi* Syd leaf rust disease	2.38–2.75
Demas-2	Agak tahan to attacks by *R. linearis*	Resistant to *Phakopsora pachirhyzi* Syd leaf rust disease	2.79–3.27
Detap-1	Resistant to attacks by *E. zinkenella* and *R. linearis*	Resistant to *Phakopsora pachirhyzi* Syd leaf rust disease	2.70–3.50

Description of soybean varieties 2016–2018 (Fattah et al., 2023a).

is one of the factors that influences the seed yield of a variety. The high seed yield in the two varieties was supported by the high number of pods in the two varieties, namely Derap-1 (45 pods) and Detap-1 (51 pods), respectively (Table 1). According to Aulia and Sartini Bayu (2014) that the high seed yield produced by the Detam-1 soybean variety is caused by the high number of pods per plant. Furthermore, Roswita et al. (2021), the seed yield achieved by a soybean variety is greatly influenced by the number of filled pods.

The high seed yield produced by a variety is not only influenced by the number of pods, but also by the size of the seeds. Sometimes there are soybean varieties that have a small number of pods but the seed yield is high because of the influence of seed size. This can be seen in the Demas-2 and Dega-1 varieties, both of which have few pods, namely only 29 pods each, but the seed yield per ha is quite high, namely 2.39–3.27 t ha^{-1} (Demas-2), respectively. and 2.78–3.82 t ha^{-1} (Dega-1) (Table 2). The high seed yield in both varieties was due to the influence of large seed size, namely 14.99 g (Demas-2) and 22.98 g (Dega-1), respectively (Table 1). This is in accordance with Damanik et al. (2013), large seed sizes give higher seed yields compared to small seed sizes.

Apart from the number of pods and seed size which influence the seed yield of each soybean variety, it is also influenced by the nature of genes for resistance to pest and disease attacks. This can be seen in the varieties Devon-1, Dena-1, and Deja-2 which have large seed sizes and a fairly high number of pods, the same as Demas-2 and Dega-1 (29 pods), but the seed yield of these three varieties is higher. Low, namely only Devon-1 (2.2–2.90 t ha $^{-1}$), Dena-1 (1.70–2.90 t ha^{-1}), and Deja-2 (2.38–2.75 t ha^{-1}), respectively (Table 2). The low seed yield of the three varieties is caused by their susceptibility to pests and diseases as shown in Table 2, the Devon-1 variety is susceptible to the pest *S. litura*, the Dena-1 variety is susceptible to attacks by the pod-sucking pests *R. linearis* and *S. litura*, and Deja −2 is susceptible to attacks by *S. litura* and *E. zinkenella* pests. According to Fattah et al. (2023b), the Dena-1 variety has a higher level of leaf damage due to *S. litura* attack (10.89%) than the Deja-1 variety (5.99%) so that the seed yield of the Dena-1 variety is also lower (1.17 ha^{-1}). compared to Deja-1 (1.21 ha^{-1}), however the Dena-1 variety has a higher seed size and number of pods per plant than the Deja-1 variety. Furthermore, Karowala and N (2015), damage to soybean leaves due to high levels of *S. litura* attack can reduce soybean seed yield. Then, Poniman et al. (2020), the Argomulyo variety had a lower level of pod damage due to *E. zinkenella* attack (13.11%) compared to Demas-1 (19.08%) so that the seed yield per plant of the Argomulyo variety was also higher (24.11 g plant^{-1}) compared to the variety Demas-1 (12.57 g plant^{-1}).

3.2 Weed management system in an effort to increase productivity

3.2.1 Effect of tillage and weed control on weeds summed dominance ratio

The SDR values of weeds before the experiment were *O. sativa* (38.58%), *A. conyzoides* (17.29%), *M. crenata* (8.36%), *E. indica* (6.99%), *A. sekili* (5.95%), *C. benghalensis* (5.20%), *P. niruri* (4.71%), *P. oleracea* (4.54%), *E. prostrata* (3.94%), *C. rutidesperm* (2.22%), *C. iria* (2.21%) (Table 3). Controlling weeds with herbicides causes the SDR value of weeds to decrease because the persistence of the herbicide in the soil can last (10–15 weeks) and is effective for controlling germinating weeds (Usman et al., 2013). However, according to other studies, herbicides are very effective in controlling weeds, so they can encourage the development of resistant biotypes (Zimdahl, 2000).

The lowest SDR value for weeds was owned by the perfect tillage treatment where weeds were controlled with herbicides, the dominant weeds were *B. oryzetorum*, *C. iria*, *C. dactylon*. On the other hand, the highest weed SDR value was owned by the perfect tillage treatment where weeds were not controlled. The dominant weeds are *E. indica*, *C. iria*, and *A. conyzoides*. so that plants (including weeds) can grow well and increase their competitiveness (Chetan et al., 2016).

During the growth of soybean plants, the lowest weed SDR value was owned by the perfect tillage treatment where weeds were controlled with herbicides; The dominant weeds were *B. oryzetorum*, *C. iria*, *C. dactylon*, while the highest SDR weed value was obtained in the perfect tillage treatment where weeds were not controlled. The dominant weed varieties that can be identified are *E. indica*, *C. iria*, and *A. conyzoides*. Similar results were also proven that the tillage method influenced changes in the weed spectrum in soybean plants, as evidenced by the application of no tillage for several years which

TABLE 3 Density value, frequency, domination, importance value, and summed dominance ratio before the experiment.

No	Types of weeds	Number	Density value		Frequency		Domination		Importance value	Summed dominance ratio
			Absolute (%)	Relative (%)	Absolute (%)	Relative (%)	Absolute (%)	Relative (%)		
1	*O. sativa* L.	38	12.67	30.65	1.67	12.50	6581.95	72.60	115.74	38.58
2	*A. conyzoides* L.	25	8.33	20.16	1.67	12.50	1740.72	19.20	51.96	17.29
3	*M. crenata* L.	12	4.00	9.66	1.67	12.50	263.36	2.90	25.06	8.36
4	*E. indica* (L.) Gaertn	12	4.00	9.66	1.33	10.00	118.44	1.31	20.98	6.99
5	*A. sessilis* (L.) R. Br	11	3.67	8.87	1.00	7.50	134.39	1.48	17.85	5.95
6	*C. benghalensis* L.	8	2.00	4.84	1.33	10.00	69.31	0.76	15.60	5.20
7	*P. niruri* L.	6	1.67	4.03	1.33	10.00	7.81	0.09	14.12	4.71
8	*P. oleracea* L.	6	2.00	4.84	1.00	7.50	117.05	1.29	13.63	4.54
9	*E. prostrate* L.	5	1.67	4.03	1.00	7.50	26.56	0.29	11.83	3.94
10	*C. rutidosperma*DC	2	0.67	1.61	0.61	5.00	4.87	0.05	6.67	2.22
11	*C. iria* L.	2	0.67	1.61	0.61	5.00	1.91	0.02	6.63	2.21

caused the growth of certain species, whereas with minimum tillage, Bromustectorum and *Agropyron repens* were monocotyledons. Weeds found before post-emergence herbicide spraying (Chețan et al., 2022). Meanwhile, *Xanthiumstrumarium* is a dicotyledonous weed that is found in all land processing methods, while *Tragopogon dubius* and *Anthemis cotula* are weeds that are found in land without tillage that has previously been tilled for at least 5 years. Other research shows that various types of weeds, *Cynodondactylon*, *Leptochloachinensis*, *Fimbristylismilacea*, *Alternantherasessilis*, *Acalyphaindica*, and *Ecliptaprostrata* are more commonly found in uncultivated land (without tillage) (Tardy et al., 2015).

Weeding treatment with simple tools once at the age of 21 days after planting will cause a decrease in the SDR value of weeds in soybean plants aged 28 days. However, the SDR value has increased because the soybean canopy has not covered the entire ground surface. This situation did not occur in the afternoon treatment with simple tools twice, namely at 21 and 42 days after planting because the soybean plant canopy covered the soil surface more densely (Moraru and Teodor, 2005). These results follow previous research that demonstrated a minimum tillage system using disc harrows, chisels, rotary harrows, milling cutters, and cover crops as mulch (Alam et al., 2014).

3.2.2 Effect of tillage and weed control on dry weed weight

The results showed that at 90 days after planting, the perfect tillage treatment where weeds were controlled by herbicides had the lowest weed dry weight, namely 2.18 kw ha^{-1}, while the perfect tillage treatment where weeds were not controlled had the highest weed dry weight. Amounting to 41.13 kw ha^{-1} (Table 4). The perfect tillage treatment was significantly different from other treatments at 28 to 90 days after planting. This treatment is caused by lifting weed seeds and tubers to the surface of the soil. Tillage treatments that reduce binding capacity (soil strength) allow weed roots to develop properly (Sebayang and Fatimah, 2018; Jat et al., 2019). Rice straw mulch can suppress weed growth, especially early growth of soybean plants, up to 28 days after planting. The role of mulch in suppressing weed growth is by blocking sunlight from reaching the soil surface (Choudhary and Kumar, 2019). The role of plant residues as mulch in a no-till system is quite large in the growth of soybean plants (Bronick and Lal, 2005; Rashidi, 2007). Apart from that, mulch derived from plant residues has many benefits, including increasing fertility, structure and soil water reserves, and is available in sufficient quantities. It was further stated that the husk mulch and straw mulch treatment with a thickness of 5 cm produced the lowest dry weight of weeds compared to other treatments (Akbar et al., 2014).

The perfect tillage treatment that controls weeds with herbicides has the lowest dry weight of weeds compared to other treatments because the resistance of the herbicide in the soil can last up to 10–15 weeks and has an effect on controlling weed germination. The sprouting stage is a stage that is sensitive to herbicides. Herbicide absorption can be through the roots, epicotyl and hypocotyl in broad-leaved weeds or the coleoptile in narrow-leaved weeds. Young leaves and young cells are also the entrance point for herbicides. Because sprouts have many herbicide entry points, the sprout stage is a stage that is sensitive to herbicides (El-Mergawi and Al-Humaid, 2019; Wang et al., 2019). The results of this study are consistent with other studies that weed biomass decreased in the second year of the

TABLE 4 The dry weight of weeds (kw ha^{-1}) due to the influence of tillage and weed control.

Treatment	Weed dry weight (kw ha^{-1})					
	28	42	56	70	80	90
	Day after transplanting (dap)					
No tillage+ weeds are not controlled	5.38 ^{c}	14.22 ^{h}	18.97 ^{i}	21.59 ^{g}	22.33 ^{f}	21.96 ^{e}
No tillage +1-time weeding	1.53 ^{b}	7.39 ^{f}	10.32 ^{g}	11.60 ^{e}	12.01 ^{d}	11.78 ^{c}
No tillage+2 times weeding	1.51 ^{b}	0.00 ^{a}	2.97 ^{c}	7.81 ^{c}	8.71 ^{b}	9.07 ^{b}
No tillage+ rice straw mulch	3.53 ^{d}	9.95 ^{g}	12.46 ^{h}	14.01 ^{f}	14.91 ^{e}	14.38 ^{d}
No tillage+ pre-emergence herbicide	0.86 ^{a}	1.08 ^{bc}	2.14 ^{b}	3.15 ^{b}	4.10 ^{a}	3.91 ^{a}
Minimum tillage + weeds are not controlled	6.57 ^{e}	17.47 ^{i}	28.89 ^{j}	33.67 ^{h}	35.16 ^{g}	35.31 ^{f}
Minimum tillage + 1-time weeding	1.03 ^{a}	5.01 ^{d}	7.41 ^{e}	8.68 ^{c}	9.44 ^{bc}	9.06 ^{b}
Minimum tillage + 2 times weeding	1.15 ^{ab}	0.00 ^{a}	2.46 ^{b}	5.79 ^{b}	7.21 ^{b}	6.75 ^{b}
Minimum tillage + rice straw mulch	2.08 ^{b}	5.78 ^{e}	8.46 ^{f}	9.66 ^{d}	10.55 ^{c}	10.25 ^{bc}
Minimum tillage+ pre-emergence herbicide	0.53 ^{a}	0.91 ^{b}	1.55 ^{a}	2.29 ^{a}	3.26 ^{a}	3.11 ^{a}
Minimum tillage+ weeds are not controlled	7.70 ^{f}	19.90 ^{j}	34.01 ^{k}	38.52 ^{i}	40.11 ^{h}	41.13 ^{g}
Perfect tillage + 1-time weeding	0.76 ^{a}	3.91 ^{c}	6.08 ^{d}	7.13 ^{bc}	8.16 ^{b}	7.80 ^{b}
Perfect tillage + 2 times weeding	0.78 ^{a}	0.00 ^{a}	2.07 ^{ab}	4.73 ^{b}	6.42 ^{b}	6.65 ^{ab}
Perfect tillage + rice straw mulch	2.06 ^{bc}	5.36 ^{d}	7.76 ^{e}	9.08 ^{cd}	9.74 ^{c}	9.48 ^{b}
Perfect tillage + pre-emergence herbicide	0.46 ^{a}	0.59 ^{b}	1.01 ^{a}	1.65 ^{a}	2.42 ^{a}	2.18 ^{a}
BNT 0.05	0.61	0.58	0.61	1.73	2.15	2.87

Followed by the same letter in a column are not significantly different LSD at 0.05 level by least significant different tested.

minimum tillage method compared to the no tillage system (Kayan and Adak, 2006; Josa et al., 2024). This is because minimal tillage is one way to maintain water content in the soil without disturbing the root system on dry land (Santín-Montanyá and Sombrero Sacristán, 2020).

3.2.3 Effect of tillage and weed control on soybean growth in the vegetative phase, weight of fresh stover, and plant biomass

The Minimum tillage+ weeds are not controlled treatment had the highest plant height (62.74 cm), while the number of leaves per plant was the highest in the Minimum tillage+ pre-emergence herbicide treatment (22.26 leaves) and the lowest in the Minimum tillage+ weeds are not controlled treatment (12.69 leaves). The highest average leaf area was found in the perfect tillage+ pre-emergence herbicide treatment (10.53 cm^2), minimum tillage+ pre-emergence herbicide (10.42 cm^2), and No Tillage+ pre-emergence herbicide (10.25 cm^2). Different approaches can be used to increase crop competitiveness, such as adjusting row spacing, optimal seeding rates, and using genotypes with high weed competitiveness. Controlling weeds with herbicides can cause low plant height due to the influence of the wrong herbicide application method, so proper application is needed to reduce the bad effects of herbicides on soybean plants. Weed control treatment with rice straw mulch showed quite high plant height values because the plants experienced etiolation due to the presence of rice straw mulch which sheltered young soybean plants (Permana et al., 2017) (Table 5).

3.2.4 Effect of tillage and weed control on soybean growth in the generative phase and seed yield

The number of flowers per plant was highest in the perfect tillage+ pre-emergence herbicide (42.23 flowers plant^{-1}), minimum tillage+pre-emergence herbicide (41.31 flowers plant^{-1}), and perfect tillage+2 times weeding treatments (40.85 flowers plant^{-1}). Meanwhile, the highest number of soybean pods per plant was also in the three treatments, namely perfect tillage+ pre-emergence herbicide (36.76 pods plant^{-1}), minimum tillage+ pre-emergence herbicide (35.53 pods plant^{-1}), and perfect tillage+2 times weeding (34.37 pods plant^{-1}). The highest number of soybean seeds per plant was perfect tillage+ pre-emergence herbicide (99.31 seeds plant^{-1}) and minimum tillage+ pre-emergence herbicide (95.42 seeds plant^{-1}). The highest dry seed weight per plant was in the perfect tillage+ pre-emergence herbicide (7.42 g plant^{-1}) and minimum tillage+ pre-emergence herbicide (7.16 g plant^{-1}) treatments. The highest dry seed weight per hectare was in the perfect tillage+ pre-emergence herbicide (18.51 kw plant^{-1}) and minimum tillage+ pre-emergence herbicide (17.83 kw plant^{-1}) treatments. The perfect tillage treatment where weeds were controlled with pre-emergence herbicides had the highest values for number of flowers, number of pods, number of seeds, stover weight and seed weight. Meanwhile, in the treatment of minimal tillage and perfect tillage without weed control, the values for the number of flowers, number of pods, number of seeds, stover weight and seed weight were the lowest. Inhibition of vegetative growth due to interference with weed growth causes the photosynthesis rate of soybean plants to decrease so that photosynthesis results in the form of carbohydrates are also reduced; Carbohydrates are needed for the formation of plant generative organs, and the formation of flowers requires carbohydrates in sufficient quantities. Flower production decreases as weed density increases due to a reduction in the number of nodes and flower production in each node, so that the number of pods formed decreases (Allen et al., 2018) (Table 6).

TABLE 5 Effect of tillage and weed control on the vegetative parameters of soybean plants at 70 days after transplanting.

Treatment	Plant height (cm)	Number of leaves per plant	Leaf area per plant	Weight of fresh stover (kw ha^{-1})	Plant biomass (g)
No tillage+ weeds are not controlled	44.83 ^{a}	13.95 ^{b}	05.72 ^{a}	28.84 ^{b}	0.968^{b}
No tillage +1-time weeding	49.51 ^{b}	15.87 ^{d}	07.63 ^{c}	34.32 ^{c}	11.95^{d}
No tillage+2 times weeding	52.65 ^{c}	17.42 ^{f}	03.36 ^{d}	40.75^{f}	13.16^{f}
No tillage+ rice straw mulch	47.38 ^{a}	15.37 ^{c}	0.684 ^{b}	32.44 ^{c}	10.81^{c}
No tillage+ pre-emergence herbicide	46.77 ^{a}	21.15 ^{j}	10.25 ^{f}	48.27 ^{i}	15.34^{i}
Minimum tillage+ weeds are not controlled	60.53 ^{e}	13.83 ^{b}	05.96 ^{a}	27.53 ^{b}	0.983^{b}
Minimum tillage+1-time weeding	53.89 ^{c}	17.87 ^{g}	08.28 ^{cd}	38.45 ^{e}	12.98^{d}
Minimum tillage+2 times weeding	52.78 ^{c}	20.35 ^{i}	09.36 ^{e}	45.72 ^{g}	14.53^{h}
Minimum tillage+ rice straw mulch	57.45 ^{d}	16.74 ^{e}	07.53 ^{c}	35.49 ^{d}	11.65^{d}
Minimum tillage+ pre-emergence herbicide	47.26 ^{a}	22.26 ^{k}	10.42 ^{f}	56.36 ^{j}	16.36 ^{j}
Minimum tillage+ weeds are not controlled	61.74 ^{e}	12.69 ^{a}	05.68 ^{a}	23.69 ^{a}	08.32^{a}
Perfect tillage+1-time weeding	56.27 ^{cd}	18.85 ^{h}	08.54 ^{d}	41.45 ^{f}	13.88^{g}
Perfect tillage+2 times weeding	55.62 ^{c}	20.41 ^{i}	09.17 ^{e}	47.24 ^{h}	15.26^{i}
Perfect tillage+ rice straw mulch	57.38 ^{d}	16.67 ^{e}	07.85 ^{c}	37.72 ^{e}	12.45^{e}
Perfect tillage+ pre-emergence herbicide	47.83 ^{a}	21.32 ^{j}	10.53 ^{f}	51.34 ^{k}	16.76^{j}
BNT 0.05	03.05	0.37	0.45	0.95	0.41

Followed by the same letter in a column are not significantly different LSD at 0.05 level by least significant different tested.

TABLE 6 The effect of tillage and weed control on the generative parameters of soybean plants.

Treatment	Number of flowers per plant	Number of pods per plant	Number of seeds per plant	Weight of dried seeds per plant (g)	Weight of dried seeds (kw ha^{-1})
No tillage+ weeds are not controlled	28.34 ^{b}	21.67 ^{a}	42.78 ^{b}	3.25 ^{b}	7.83 ^{b}
No tillage +1-time weeding	34.57 ^{d}	28.37 ^{b}	67.44 ^{d}	5.05 ^{d}	13.67 ^{f}
No tillage+2 times weeding	36.73 ^{de}	30.25 ^{c}	75.21 ^{e}	5.63 ^{e}	14.45 ^{g}
No tillage+ rice straw mulch	31.78 ^{c}	25.83 ^{b}	55.48 ^{c}	4.11 ^{c}	10.64 ^{c}
No tillage+ pre-emergence herbicide	37.35 ^{e}	31.62 ^{cd}	79.34 ^{ef}	5.96 ^{f}	14.75 ^{g}
Minimum tillage+ weeds are not controlled	26.86 ^{a}	20.78 ^{a}	38.85 ^{a}	2.93 ^{a}	6.54 ^{a}
Minimum tillage+1-time weeding	35.44 ^{d}	29.81 ^{c}	71.46 ^{de}	5.37 ^{de}	13.78 ^{f}
Minimum tillage+2 times weeding	39.75 ^{f}	33.43 ^{d}	87.54 ^{fg}	6.53 ^{g}	16.22 ^{f}
Minimum tillage+ rice straw mulch	33.83 ^{f}	27.55 ^{b}	59.27 ^{c}	4.49 ^{c}	11.36 ^{d}
Minimum tillage+ pre-emergence herbicide	41.31 ^{g}	35.53 ^{e}	95.42 ^{gh}	7.16 ^{gh}	17.83 ^{k}
Minimum tillage+ weeds are not controlled	25.77 ^{a}	19.84 ^{a}	34.58 ^{a}	2.64 ^{a}	6.32 ^{a}
Perfect tillage+1-time weeding	38.65 ^{ef}	32.44 ^{d}	83.96 ^{f}	6.78 ^{g}	15.54 ^{h}
Perfect tillage+2 times weeding	40.85 ^{fg}	34.37 ^{de}	91.35 ^{g}	6.83 ^{g}	17.07 ^{j}
Perfect tillage+ rice straw mulch	34.48 ^{d}	28.68 ^{bc}	63.98 ^{cd}	4.78 ^{cd}	12.42 ^{e}
Perfect tillage+ pre-emergence herbicide	42.23 ^{gh}	36.76 ^{e}	99.31 ^{h}	7.42 ^{h}	18.51 ^{L}
BNT 0.05	1.90	2.59	4.87	0.50	0.41

Data followed by the same letter in a column are not significantly different at 0.05 level by least significant different tested.

3.3 Relationship between plant growth parameters and dry weight components of weeds and soybean seed yield

3.3.1 Relationship between growth components and dry weight of weeds

Stratified regression analysis showed that the dry weight of weeds had the greatest influence on the leaf area of soybean plants at 56 days after planting.

$$\hat{Y} = 67.11 - 3.62 \times 3$$

$$R2 = 0.84^{*} \quad (1)$$

In the (Equation 1), the dry weight of weeds is negatively correlated with all soybean plant growth parameters (number of leaves, leaf area and biomass) except plant height. Based on stratified regression analysis, R2 = 0.84** shows that the dry weight of weeds has the greatest influence on the leaf area of soybean plants at 56 days after planting. According to Sebayar and Rifai (2018), perfect tillage means the leaf area is 14.38% wider than with minimum tillage and 16.94% higher than without tillage at the age of soybean plants 55 days after planting. Meanwhile, Prasetyo et al. (2014) that the leaf area of soybean plants that are perfectly cultivated with minimal tillage is not significantly different but is much wider than soybean plants without tillage.

3.3.2 Effect of weeds on soybean yield

Based on multilevel regression analysis, it shows that the dry weight of weeds has the most influence on soybean yield at 56 days after planting.

$$\hat{Y} = 17.06 + -1.59 \times 3$$

$$R2 = 0.90^{**} \quad (2)$$

The dry weight of weeds is negatively correlated with soybean yield. Based on multilevel regression analysis (Equation 2), R2 = 0.90** shows that the dry weight of weeds has the greatest influence on soybean yield. According to Muaz Munauwar and Dan (2022), the presence of weeds around soybean plantings will cause competition for nutrients, water, light and growing space between weeds and soybeans, causing the growth of soybeans to be hampered and seed yields to decrease.

Based on stratified regression analysis it has a positive relationship with soybean yield. Shows that the largest contribution of soybean yield components to soybean yield is the number of seeds per plant.

$$\hat{Y} = 6.38 + 0.17 \times 3$$

$$R2 = 0.99^{**} \quad (3)$$

The (Equation 3), it gives an indication that the soybean yield components (number of flowers per plant, number of pods per plant, number of pods per plant, oven dry seed weight, weight of 100 seeds) have a positive correlation with soybean yield. Based on the stratified regression analysis R2 = 0.99**, it indicates that there is the largest contribution of soybean yield components (number of flowers per plant, number of pods per plant, number of seeds per plant, oven dry seed weight, weight of 100 seeds) to soybean yield. According to Patriyawaty and Anggara (2020), that the number of leaves and flowers is positively correlated with soybean seed yield. This means that the higher the number of leaves and the number of flowers per plant, the higher the soybean seed yield.

4 Conclusion

Each soybean variety has different characteristics and characteristics of resistance and susceptibility to pest and disease attacks. Derap-1, Detap-1, Deja-1, Devon-1 and Deja-2 are resistant to attacks by *E. zinkenella* and *R. linearis* pests. Dena-2 is resistant to *S. litura*. Dena-1, Devon-1, Dega-1, and Deja-2 suscepible *S. litura*. The characteristics of these varieties will also influence vegetative growth parameters such as plant height, number of branches and leaf area as well as influence generative growth parameters such as number of pods and weight of 100 seeds. These differences in characteristics will influence the high and low seed yields per plant achieved by a soybean variety.

Perfect tillage where weeds are controlled with pre-emergent herbicides has the lowest Total SDR and weed dry weight. The identification results show that the dominant weed in soybean planting is *C. iria* or *B. oryzetorum*. Perfect tillage where weeds are not controlled has the highest Total Dominance Ratio (SDR) and weed dry weight. Based on the identification results, it was found that the dominant weeds were *O. sativa, A. conyzoides*, and *E. indica*. The dry weight of weeds was negatively correlated with growth parameters and seed yield of soybean plants and all soybean plant growth parameters were positively correlated with soybean yield, especially leaf area at 56 days after planting. All components of vegetative and generative growth are positively correlated with soybean yield.

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

AF: Conceptualization, Investigation, Resources, Supervision, Writing – original draft, Writing – review & editing. AN: Conceptualization, Formal analysis, Methodology, Resources, Validation, Writing – original draft, Writing – review & editing. KS: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Supervision, Writing – original draft, Writing – review & editing. MH: Conceptualization, Methodology, Supervision, Visualization, Writing – original draft, Writing – review & editing. AA: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. PB: Conceptualization, Methodology, Resources, Supervision, Writing – original draft, Writing – review & editing. EN: Writing – original draft, Writing – review & editing. AP: Writing – original draft, Writing – review & editing. SS: Conceptualization, Investigation, Methodology, Resources, Writing – original draft, Writing – review & editing. NN: Writing – original draft, Writing – review & editing. EL: Writing – original draft, Writing – review & editing. ZA: Writing

– original draft, Writing – review & editing. NI: Writing – original draft, Writing – review & editing. BU: Writing – original draft, Writing – review & editing. WD: Writing – original draft, Writing – review & editing.

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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.

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