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Study on Population Density and Mulch Effectiveness in Early Growth of Onions Seedlings and Weed Dynamics

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Abstract. Onion cultivation (*Allium cepa*), known as “bawang Bombai,” is relatively new in Indonesia, a tropical region. It can be done using transplanting or direct seed planting (DSP). Farmers favor DSP as it eliminates the need for a separate nursery; however, optimal seedling density and effective weed control are crucial during the early growth stages. This study, conducted in Yogyakarta from May to July 2024, investigated the impact of onion seedling density and mulch on early growth using DSP. The experimental design features a split-plot arrangement with four replications. The main plot involved the mulch treatments (none and plastic mulch), while the subplot examined seedling densities (2, 4, 6, and 8 g per m²). Results showed no interaction between seedling density and mulch on any variables. Treatments did not significantly affect seedling emergence, plant height, or leaf number. Plastic mulch reduced total weed emergence, but the difference was not significant compared to no mulch during the early growth phase. However, higher seedling densities could suppress total weed emergence. *Eleusine indica* and *Portulaca oleracea* were the dominant weed species during the early growth stage. Plastic mulch was only effective in suppressing the emergence of *Eleusine indica*. In contrast, *Portulaca oleracea* emergence could not be suppressed by either plastic mulch or increased seedling density in the bed. The findings suggest that using plastic mulch can effectively manage weeds in an early growth phase, particularly *Eleusine indica*, making this practice beneficial for farmers.

Keywords: mulch, short-day onion, seedlings, tropical region, weed control



1. Introduction

Onions (*Allium cepa* L.) are the second-most widely cultivated vegetable globally, after tomatoes. [1]. Originating from Central Asia, onions have spread worldwide and become a staple food in many regions. The benefits of onions are diverse, encompassing both nutritional and health aspects. Onions are rich in antioxidants such as quercetin, which has anti-inflammatory and anticancer properties. [2]. Additionally, onions contain vitamin C, B6, dietary fiber, and bioactive compounds that benefit consumers. [3].

Indonesia's annual demand for onions averages 120,000 to 130,000 tons, which is nearly met through imports. Onion cultivation in Indonesia has not developed significantly because the available varieties are typically long-day types that require more than 16 hours of daylight. Brewster [4] stated that the primary environmental trigger for the start of bulbing in onions is day length. Nowadays, the development of short-day onion varieties, which require 11-12 hours of daylight [5], presents an opportunity for onion cultivation in Indonesia's tropical climate.

Similar to shallots, which are propagated from seeds, the early growth phase from germination to the formation of three leaves is critical for onion development. [6]. In the Southwestern United States, most short-day onion cultivars are direct seeded. During early development, onion seedlings are highly susceptible to soil-borne diseases, extreme temperatures, and weeds, often reducing plant stands. [7]. Farmers typically increase seedling density to compensate for the loss of plant population using the direct-seeded technique. [8] Research on seeding density to achieve optimal seedling populations in the field is crucial for the successful early growth of seedlings. Additionally, efforts to reduce weed growth during the early seedling stage are important, as weeds compete for water and nutrients, and their roots can inhibit the seedling growth. Early season weed competition significantly reduces onion bulb yield [9]. Weeds compete with young seedlings for essential resources such as light, water, and nutrients, reducing growth rates and weakening plant vigor. Due to its natural characteristics, the onion's ability to compete with weeds is inferior. This is due to its shallow root system, slow growth during early stages, unbranched growth habit, restricted foliage, and prolonged growth during the early stages. Tewari [10] reported that yield losses from weed infestation in onions could reach 82.2%.

The use of mulch in onion cultivation is a widely accepted practice in Western countries. Mulching, particularly plastic mulch, offers numerous benefits, including maintaining soil moisture, suppressing weed growth, regulating soil temperature, and improving soil structure. Plastic mulch is particularly advantageous due to its ability to create favourable diurnal soil temperature patterns and a wider canopy air temperature range, thereby reducing seedling mortality and enhancing plant growth [11,12] The use of plastic mulch to suppress weed growth in onions in tropical regions, such as Indonesia, has not been widely reported, especially during the early growth stages.

This study aims to determine whether plastic mulch can effectively control weeds during the early growth of short-day onion seedlings in lowland tropical climates and whether variations in seeding density affect seedling quality.

2. Materials and Methods

2.1. Location and treatment

The experiment occurred in Baturetno Village, Banguntapan sub-district, Bantul District, Yogyakarta (116 m above sea level) from May to July 2024. Analysis of the physical-chemical properties of this land shows that the soil has a loam texture, with a slightly alkaline pH (7.15). It used the short-day onion "Trophy" in a split-plot design with four replications. The main plot compared two mulch treatments (no mulch and plastic mulch), while the subplot examined seed densities (2, 4, 6, and 8 g per m²) based on [13,14] with modifications for onion seed.

The seeds were directly planted in beds that had previously been managed with isopropylamine salt of glyphosate (486 g.L⁻¹), followed a month later by paraquat dichloride (276 g.L⁻¹). A base fertilizer consisting of fermented goat manure (20 tons ha⁻¹; 2.0 kg m⁻²), dolomite (3 tons ha⁻¹; 300 g m⁻²), and SP-26 phosphate fertilizer (150 kg ha⁻¹; 15 g m⁻²) was applied to the seedling furrows at 20 cm, one week before planting. The beds were then covered with 4 cm of perforated plastic mulch, parallel to the furrow spacing, according to the treatment. Seeds were sown manually to a depth of approximately 1.5 cm, with placement adjusted according to seed density and mulch treatment. The beds were irrigated with a low-pressure sprayer (<1.5 bar; 150 kPa) to ensure gentle, uniform water application, thereby minimizing soil disturbance and preventing seed displacement. Irrigation was performed daily. Observations were made two weeks after sowing (WAS). The soil water content was measured using gravimetric methods. Fresh soil samples were weighed, oven-dried at 105 ± 2 °C for 24 hours until a constant weight was achieved, and then reweighed. Gravimetric water content was calculated as the ratio of water loss to dry soil weight [15].

Environmental conditions were monitored using a digital thermo-hygrometer (HTC-2 Digital Thermo-hygrometer, China) to record air temperature (average 35.3 °C, maximum 33.2 °C, and minimum 28.9 °C) and relative humidity (74.2%). Light intensity was measured with a digital lux meter (LX-103 Light Meter, Taiwan), averaging 48,119 lux under a 12-hour natural photoperiod. Measurements were taken daily at 08:00, 12:00, and 16:00 throughout the experimental period, and mean values were calculated to describe the prevailing conditions.

2.2. Statistical analysis and Variables Measurement

The observed variables included seedling survival rate, plant height, number of leaves, number of dominant weeds, Summed Dominance Ratio (SDR), weed dry weight, and the incidence of pests and diseases was visually assessed at two weeks after sowing (2 WAS) by observing the presence or absence of visible symptoms on seedlings, following standard visual assessment principles as described by [16] and later refined by [17]. The Summed Dominance Ratio (SDR) is calculated as follows [18]:

$$SDR_i = \frac{RD_i + RF_i + RDM_i}{3}$$

Where:

RD_i (Relative Density (%)) = $(n_i / \Sigma n) \times 100 \%$

RF_i (Relative Frequency (%)) = $(f_i / \Sigma f) \times 100 \%$

RDM_i (Relative Dry Mass (%)) = $(w_i / \Sigma w) \times 100 \%$

n_i = number of individuals of species i

f_i = frequency of occurrence of species i

w_i = dry weight of species i

Σn , Σf , Σw = totals of all weed species in the sample

SDR values were compared descriptively, while other weed parameters were analyzed using ANOVA followed by Duncan's Multiple Range Test (DMRT) at the 5% level

3. Results and Discussion

3.1. Effect of using plastic mulch on soil water content

The research was conducted during the dry season, which is suitable for direct field planting. Rainfall can damage young seedlings early in their growth, while using shade increases farming costs. Plastic mulch was applied to assess its potential to reduce evaporation and alleviate seedling dryness. The results of measuring soil water content when using plastic mulch are presented in Figure 1.

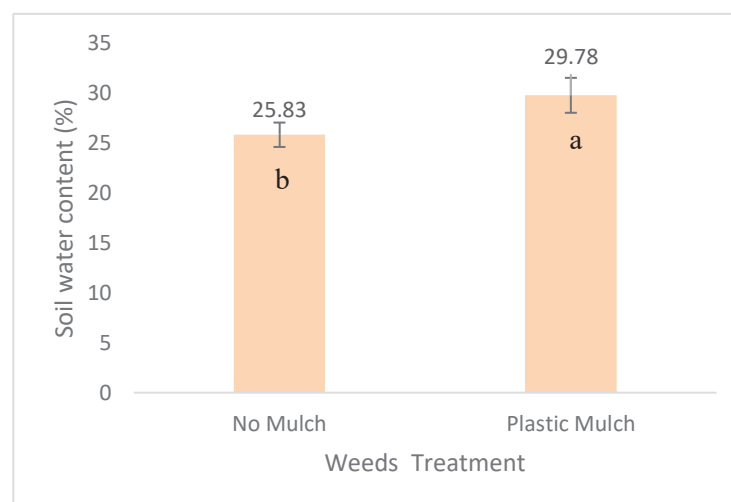


Figure 1. Soil water content under mulch treatment during the early growth of onion seedling beds.

After 24 hours of irrigation, the soil water content with plastic mulch treatment was significantly higher (29.78%) than with no mulch (25.83%). This implies that plastic mulch helps minimize evaporation, enabling the soil to retain more moisture than when no mulch is applied. Plastic mulch effectively conserves soil moisture, potentially reducing irrigation needs and improving plant growth conditions. This result is compatible with [19] who report that plastic mulch helps retain soil moisture, reduces evaporation, and improves water use efficiency.

3.2. Early seedling growth phase

The early growth phase of onion seedlings (*Allium cepa*) is crucial in establishing the foundation for healthy, robust development throughout the plant's lifecycle. In this initial stage, competition with weeds is a primary challenge for onion seedlings, and population density can significantly influence their ability to thrive. This experiment employs proper management practices, including mulching and controlling population density, to minimize competition and ensure optimal growth conditions. The seedling survival rate, plant height, and number of leaves are presented in Table 1.

The seedling survival rate observed in this study, which ranged from 62% to 64% (Table 1) for both mulched and non-mulched treatments, is still below the minimum germination standard of 70% for onion seeds. [20]. This shortfall suggests that, when employing direct seeding methods, a higher sowing density may be necessary, as field conditions might not be ideal for achieving optimal germination rates, even with high-viability seeds. Plastic mulch did not increase the seedling survival rate compared to the control bed without it. The lowest seedling density of 2 grams per square meter achieved the highest survival rate of 74%. However, this was not significantly different from the 57% survival rate observed

at a density of 8 grams per square meter. This result indicates that the higher seed density of 8 grams per square meter does not markedly impair seedling growth compared to using a lower density, at least within the first two weeks after sowing.

Table 1. The seedling survival rate, plant height, number of leaves in different mulch treatments and seedling densities at two weeks after sowing (WAS)

Variables	Mulch	Seed Density (g/m ²)				Mean
		2	4	6	8	
Seedling Survival Rate (%)	No Mulch	81.46	55.16	65.78	51.76	62.34
	Plastic Mulch	68.75	55.23	67.97	63.13	63.77
CV = 27.05%	Mean	74.20	55.20	66.88	57.44	(-)
Plant Height (cm)	No Mulch	6.52	6.71	6.28	6.73	6.56
	Plastic Mulch	6.36	6.16	6.04	6.20	6.19
CV = 9.56%	Mean	6.44	6.43	6.16	6.46	(-)
Number of leaves	No Mulch	1.78	1.70	1.98	1.75	1.80
	Plastic Mulch	1.95	1.88	1.90	1.98	1.93
CV = 9.32%	Mean	1.86	1.79	1.94	1.86	(-)

Note: Values with different letters are significantly different based on the DMRT test, $\alpha = 0.05$.

Different plastic mulch treatments and seedling densities did not affect plant height or leaf number (Table 1). Increasing seedling density up to 8 g/m² did not cause growth stress due to competition. This is because the need for water, nutrients, and sunlight in seedlings is not high, so it has not affected growth in 2 WAS. In this study, the soil water content in the control was 34.86% (Figure 1); this is still sufficient for the water needs of the onion seedling, so plastic mulch does not cause a significant difference in seedling growth compared to the control without plastic mulch. This was conveyed by [8], who stated that onions are susceptible to water stress during the early growth phase, which can reduce yields, especially under high seedling density. However, if water needs are adequate, increasing seedling density can increase yields.

During the seedlings' initial growth period (2 WAS), no pest or disease incidence was observed, indicating that other biotic stresses did not constrain seedlings. Thus, weed emergence and competition represented the only biotic stress at this stage, consistent with previous reports highlighting early weed interference as the primary constraint during crop establishment in maize and rice [21,22].

3.3. Weed Growth Dynamics During Seedling Emergence

Weeds are generally more resilient to unfavorable conditions, such as drought and low soil fertility, allowing them to thrive where seedlings struggle to establish. Observations of early seedling growth showed no significant differences between mulch treatments and seedling densities during the first two weeks after sowing. Additionally, weed growth in the early stages of onion seedling development was monitored to identify the dominant weeds emerging and assess their potential risks to onion seedling growth. Table 2 presents the analysis results for the number of each of these two weed species found in the bed and their dry weight.

The result revealed no significant interaction between the mulch application treatment and seedling density on the number and dry weight of the weeds, either partially or in total. The differences in weed dynamics were more due to mulch treatment or seed density than to the interaction.

Additionally, seedling density plays a role in weed suppression, with densities of 6 and 8 grams per square meter effectively limiting the number of *E. indica*. Nevertheless, seedling density did not significantly affect the dry weight of *E. indica*, *P. oleracea*, or total weeds two weeks post-sowing.

Table 2. Weed Growth Dynamics in different mulch treatments and seedling densities at two weeks after sowing (WAS)

Variables	Mulch	Seed Density (g.m ⁻²)				Mean
		2	4	6	8	
Number of <i>Eleusine indica</i> * CV = 13,90%	No Mulch	22.50	20.75	15.25	9.25	16.94
	Plastic Mulch	10.75	13.75	5.50	7.75	9.44
	Mean	16.63 b	17.25 b	10.38 ab	8.50 a	(-)
Number of <i>Portulaca oleracea</i> * CV = 18,91%	No Mulch	8.25	5.75	6.75	7.75	7.13
	Plastic Mulch	11.00	17.00	10.00	6.50	11.13
	Mean	9.63	11.38	8.38	7.13	(-)
Number of total weeds* CV = 14,31%	No Mulch	30.75	26.50	22.00	17.00	24.06
	Plastic Mulch	21.75	32.00	15.50	15.25	21.13
	Mean	26.25 b	29.25 b	18.75 a	16.13 a	(-)
<i>Eleusine indica</i> Dry Weight* (g) CV = 9,82%	No Mulch	0.76	0.59	0.48	0.37	0.55 b
	Plastic Mulch	0.25	0.37	0.12	0.16	0.22 a
	Mean	0.50 b	0.48 b	0.30 a	0.26 a	(-)
<i>Portulaca oleracea</i> Dry Weight* (g) CV = 8,41%	No Mulch	0.15	0.20	0.25	0.23	0.21
	Plastic Mulch	0.26	0.47	0.22	0.11	0.26
	Mean	0.21	0.34	0.23	0.17	(-)
Total Weeds Dry Weight * (g) CV = 11,60%	No Mulch	0.91	0.79	0.73	0.59	0.75
	Plastic Mulch	0.50	0.84	0.34	0.27	0.49
	Mean	0.71	0.82	0.53	0.43	(-)

Note: Values with the same letters are not significantly different based on the DMRT test, $\alpha=0.05$.

The analysis of the Summed Dominance Ratio (SDR) in Figure 2 showed that in the control plots without mulch (M0), *E. indica* consistently exhibited higher SDR values (57–73%), indicating its strong competitive ability under open-field conditions. This grass weed possesses a vigorous fibrous root system, rapid seedling growth, and high adaptability to resource-limited environments, which enable it to outcompete broadleaf species during the early growth stage [18]. Conversely, in the mulched plots (M1), the dominance shifted toward *P. oleracea* in several replicates (SDR > 50%). This shift suggests that plastic mulch effectively reduced the emergence and biomass of *E. indica* but was less effective in suppressing *P. oleracea* (Purslane). The succulent growth habit of purslane, its ability to regenerate from stem fragments, and its flexible photosynthetic pathway (C4 with facultative Crassulacean Acid Metabolism (CAM) metabolism) contribute to its persistence even under partially shaded or mulched conditions [23].

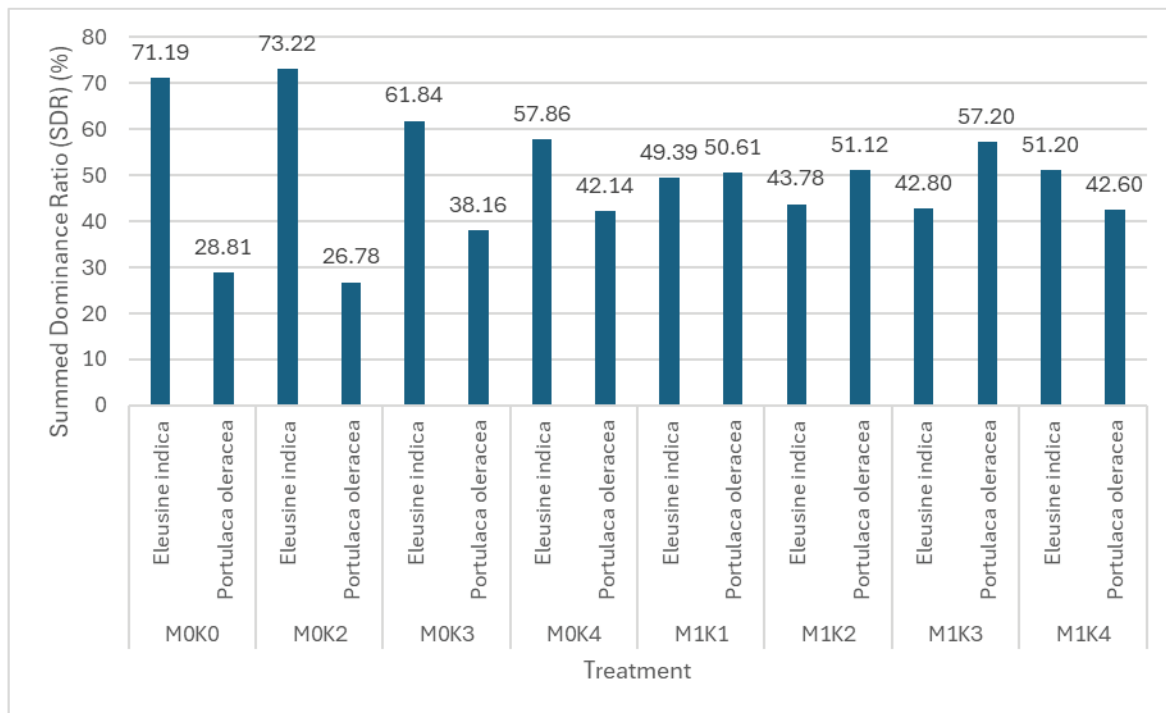


Figure 2 Summed Dominance Ratio (SDR) in different mulch treatments and seedling densities at two weeks after sowing (WAS).

Noted: M0 =No Mulch; M1 = Plastic mulch

K0 = seed density 2 g per m²; K1 = 4 g per m²; K3 = 6 g per m²; K4 = 8 g per m².

Onion population density also influences weed dynamics, which is reflected in weed abundance and biomass production. Higher seeding densities reduce the number of *E. indica* individuals and the total weed population. This suggests that denser plant stands restrict the ecological niches available to weeds. This is consistent with the principle of plant-weed competition, which states that higher plant density increases competitive ability by limiting access to light, nutrients, and water. Although the effects were not always statistically significant, the observed trend is consistent with previous studies, which report that higher plant density can inhibit weed growth (Knezevic et al., 2002; Olsen et al., 2012; Wu et al., 2021).

Mulching further suppresses weeds by altering the soil microenvironment. Plastic mulch reduces light penetration at the soil surface and regulates soil moisture, thereby limiting germination and dry matter accumulation of *E. indica* (Lamont, 2005; Chakraborty et al., 2008). However, *P. oleracea* proved more resilient under mulched conditions. This is due to adaptive traits such as vegetative regeneration and facultative CAM metabolism, which enable survival under fluctuating conditions (Proctor, 2013). For example, SDR analysis showed that *E. indica* dominated in the unmulched treatment, while *P. oleracea* became more competitive under mulched conditions.

Overall, the interplay of planting density and mulch shaped the structure of the weed community. Higher planting density reduced weed pressure, while mulch use shifted dominance from grasses to broadleaf weeds. The result underscores the need for an integrated strategy to effectively control both weed groups during the critical early stages of onion seedling development.

Herbicides are the recommended method for controlling *Eleusine indica*. However, further investigation is necessary when using herbicides at the early stages of onion growth, as *E. indica* has developed resistance to glyphosate and glufosinate through mechanisms such as target-site mutations and enhanced metabolic processes, making control more challenging. [24] Herbicides such as clethodim, haloxyfop, and glyphosate can control over 88% of *E. indica* when applied during the appropriate

growth phases. The bioherbicide Unihaz formulation, applied at 70 L/ha, results in substantial weed mortality and a reduction in *E. indica* biomass.[25]

This study underscores that while plastic mulch increased soil water content, it did not significantly enhance the early growth of onion seedlings. Notably, increasing the seed density to 8 g per square meter did not negatively affect seedling quality compared to a lower density of 2 g per square meter, measured two weeks after sowing (WAS). Critical growth indicators, such as seedling survival rate, plant height, and leaf number, showed no significant differences between treatments during the first two weeks. These findings suggest that, under the conditions tested, neither plastic mulch nor increased seed density substantially affected the early development of onion seedlings. Additionally, no serious pest or disease outbreaks were observed across treatments during the first two weeks. However, weed presence was a considerable challenge in the planting beds.

Regarding weed management, plastic mulch displayed limited effectiveness in suppressing dominant weed species such as *Portulaca oleracea* and *Eleusine indica*. Although mulch reduced the dry weight of *E. indica*, it did not entirely prevent weed emergence. Interestingly, higher seed densities slightly decreased the number of *E. indica* plants, though this did not significantly affect total weed biomass or dry weight. Given the resilience of *P. oleracea* and the adaptability of *E. indica*, these results suggest the need for further research into more comprehensive weed control strategies for onions. Such strategies could include combining plastic mulch with manual weed removal or using herbicides to better protect young onion seedlings from early weed competition.

4. Conclusion

This study demonstrated that planting density and mulching onions significantly impacted the dynamics of the weed community during the early seedling stage. Higher planting density reduced overall weed pressure, while plastic mulch suppressed *E. indica* but allowed for stronger competition from *P. oleracea*. Importantly, increasing seed density to 8 g m⁻² did not compromise seedling quality compared with the lower density of 2 g m⁻², indicating that higher seeding rates can be applied without detrimental effects at two weeks after sowing.

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References

- [1] FAO (Food and Agriculture Organization of the United Nations) 2024 Onion Production. <https://www.fao.org/faostat/en/#data/QCL>
- [2] Benkeblia N 2004 Antimicrobial activity of essential oil extracts of various onions (*Allium cepa*) and garlic (*Allium sativum*) *LWT* **37** 263–8
- [3] Griffiths G, Trueman L, Crowther T, Thomas B and Smith B 2002 Onions - A global benefit to health *Phytotherapy Research* **16** 603–15
- [4] Brewster J L 1990 Physiology of crop growth and bulbing *Onions Allied Crops Volume I: Botany, Physiology, and Genetics* ed H D Rabinowitch and J L Brewster (Boca Raton, Florida: CRC Pres) pp 53–89
- [5] Mondal M F, Brewster J L, Morris G E L and Butler H A 1986 *Bulb Development in Onion (Allium cepa L.) III. Effects of the Size of Adjacent Plants, Shading by Neutral and Leaf Filters, Irrigation and Nitrogen Regime and the Relationship between the Red: Far-red Spectral Ratio in the Canopy and Leaf Area Index* vol 58

- [6] Pangestuti R, Sulistyaningsih E, Kurniasih B, Murti R H, Harper S and Subandiyah S 2023 Phenological growth stage of tropical shallot (*Allium cepa* L. *Aggregatum* group) planted from seed in lowland area based on the BBCH scale *Annals of Applied Biology* **182** 257–66
- [7] Leskovar D I, Agehara S, Yoo K and Pascual-Seva N 2012 Deficit Irrigation and Plant Density Impact on Growth, Yield, Quality and Quercetin of Short-Day Onion *Acta Horticultura* vol 936 (ISHS) pp 219–26
- [8] Leskovar D I, Agehara S and Yoo K 2012 *Crop Coefficient-based Deficit Irrigation and Planting Density for Onion: Growth, Yield, and Bulb Quality* vol 47
- [9] Urraiya P and Kumar Jha M 2017 Weed management studies in kharif onion (*Allium cepa* L.) on yield attributes ~ 14 ~ *Journal of Pharmacognosy and Phytochemistry* **6** 14–6
- [10] Tewari A N, Tiwari S N, Rath J P S, Singh B and Tripathi A K 2023 Studies on Crop-weed Competition in Kharif Onion (*Allium cepa* L.) *Indians Journals of Weed Science* **35** 156–8
- [11] Barla S and Upasani R R 2019 Study on Different Methods of Weed Management in Onion (*Allium cepa* L.) *Current Journal of Applied Science and Technology* 1–7
- [12] Urraiya P and Kumar Jha M 2017 Weed management studies in kharif onion (*Allium cepa* L.) on yield attributes ~ 14 ~ *Journal of Pharmacognosy and Phytochemistry* **6** 14–6
- [13] Sumarni N and Rosliani R 2010 Pengaruh Naungan Plastik Transparan, Kerapatan Tanaman, dan Dosis N terhadap Produksi Umbi Bibit Asal Biji Bawang Merah *Jurnal Hortikultura* **20** 52–9
- [14] Pernando J and Damanhuri D 2019 Pengaruh Populasi dan Teknik Penyemaian Benih Tss terhadap Pertumbuhan dan Hasil Benih Umbi Bawang Merah (*Allium cepa* L.) Effect of Population and Tss Sowing Techniques on Growth and Yield of Shallots (*Allium cepa* L.) *Jurnal Produksi Tanaman* **7** 1679–86
- [15] Rasheed M W, Tang J, Sarwar A, Shah S, Saddique N, Khan M U, Imran Khan M, Nawaz S, Shamshiri R R, Aziz M and Sultan M 2022 Soil Moisture Measuring Techniques and Factors Affecting the Moisture Dynamics: A Comprehensive Review *Sustainability (Switzerland)* **14**
- [16] Clive James W *An Illustrated Series of Assessment Keys for Plant Diseases, Their Preparation And Usage* vol 51
- [17] Bock C H, Poole G H, Parker P E and Gottwald T R 2010 Plant disease severity estimated visually, by digital photography and image analysis, and by hyperspectral imaging *CRC Crit Rev Plant Sci* **29** 59–107
- [18] Głowacka A 2011 Dominant Weeds in Maize (*Zea Mays* L.) Cultivation and Their Competitiveness Under Conditions of Various Methods of Weed Control *Acta Agrobot* **64** 119–26
- [19] Coelho E F, Santos D L, Lima L W F de, Castricini A, Barros D L, Filgueiras R and da Cunha F F 2022 Water regimes on soil covered with plastic film mulch and relationships with soil water availability, yield, and water use efficiency of papaya trees *Agric Water Manag* **269**
- [20] FAO (Food and Agriculture Organization of the United Nations) 2008 *Seed and Seed Quality: Technical Information for FAO Emergency Staff* (Rome)
- [21] Knezevic S Z, Evans S P, Blankenship E E, Van Acker R C and Lindquist J L 2002 Critical period for weed control: the concept and data analysis *Weed Sci* **50** 773–86
- [22] Rao A N, Johnson D E, Sivaprasad B, Ladha J K and Mortimer A M 2007 Weed Management in Direct-Seeded Rice *Advances in Agronomy* **93** 153–255
- [23] Proctor C A 2013 *Biology and Control of Common Purslane (Portulaca Oleracea L.)* Dissertation (Nebraska: University of Nebraska)
- [24] Simarmata M, Apriantone R, Setyowati N and Pujiwati H 2023 Possibility of glyphosate-resistant goosegrass (*Eleusine indica*) in citrus fields in Rejang Lebong Districts, Bengkulu, Indonesia *Biodiversitas* **24** 3624–9
- [25] Tejada J L, Barroso A A M, Solis-Rosas-Diaz L F, Alvarado-Huamán L, Silva E and da Costa Aguiar Alves P L 2024 Post-emergent herbicides to control goose grass (*Eleusine indica* L.) in pre-tillering and tillering stages *Revista U.D.C.A Actualidad and Divulgacion Cientifica* **27** 1–6