ANALYSIS OF THE PERFORMANCE OF A PLASTIC MULCH PUNCHING MACHINE / *ANALISIS KINERJA MESIN PELUBANG MULSA PLASTIK*

Mustaqimah MUSTAQIMAH *1), Muhammad ANAS MUFTI 1), Ramayanty BULAN 1), Oscar HARIS 2)
1) Department of Agricultural Engineering, Faculty of Agriculture, Syiah Kuala University, Indonesia
2) Department of Automotive Industrial Engineering Technology, Boash Indonesia Digital Polytechnic, Indonesia
Tel: +62 921-6484-6042; E-mail: mustaqimah@unsyiah.ac.id
DOI: https://doi.org/10.35633/inmateh-68-72

Keywords: *agriculture machinery, appropriate technology, perforation machinery, rotational speed*

ABSTRACT
This study aims to determine the performance of a plastic mulch hole making machine and its electrical power requirements. The study begins by providing speed variations on the engine sprocket, calculating the working capacity of the machine, and analysing the power requirements of the electric motor. The results showed that the engine sprocket could perform an optimal rotation speed for punching holes in plastic mulch. Most holes were created in the treatment with a rotational speed of 70 rpm, 16 holes per 5 m of plastic mulch. Overall, the performance of the plastic mulch punching machine has been able to provide fixes in making holes in mulch plastic. Of the three treatments, the speed variations of the plastic mulch punching machine provided perforations with the criteria of perfect and partial perforation. The highest percentage of ideal perforation was found in the treatment with a rotational speed of 29 rpm, 86%, and the lowest was found in the treatment with a rotational speed of 25 rpm, 9.3%. The coefficient of determination between the rotational speed of the machine and the performance of the machine to punch holes in the plastic mulch can be modelled by a polynomial equation.

ABSTRAK
Penelitian ini bertujuan untuk mengetahui unjuk kerja mesin pembuat lubang mulsa plastik dan kebutuhan daya listriknya. Penelitian diawali dengan memberikan variasi kecepatan pada engine sprocket, menghitung kapasitas kerja mesin, dan menganalisis kebutuhan daya motor listrik. Hasil penelitian menunjukkan bahwa sproket mesin dapat melakukan kecepatan putaran optimal untuk lubang pelubangan mulsa plastik. Lubang terbanyak tercipta pada perlakuan dengan kecepatan putar 70 rpm, 16 lubang per 5 m mulsa plastik. Hasil kinerja mesin pelubang mulsa plastik telah mampu memberikan perbaikan pada mulsa plastik. Dari ketiga perlakuan variasi kecepatan pada mesin pelubang mulsa plastik memberikan perforasi dengan kriteria perforasi sempurna dan sebagian. Persentase perforasi ideal tertinggi terdapat pada perlakuan dengan kecepatan putar 29 rpm sebesar 86%, dan terendah pada perlakuan dengan kecepatan putar 25 rpm sebesar 9.3%. Koefisien determinasi antara kecepatan putar mesin dan kinerja mesin dalam melubangi plastik mulsa dapat dimodelkan dengan persamaan polinomial.

INTRODUCTION
Mulch is a material to cover the soil so that moisture and soil temperature as a medium of plants maintain stability, suppress weed populations and diseases, and avoid splashing rainwater directly onto the ground surface, resulting in erosion (*Tinambunan et al.*, 2014). The use of mulch provides several benefits in terms of biological, physical, and chemical aspects of the soil. Mulch can physically maintain a more stable soil temperature (*Utomo and Agus Suryanto*, 2013). Mulching on land can also prevent water loss through evaporation (*Pribadi et al.*, 2014). The use of mulch can also provide benefits, such as saving water use by reducing the rate of evaporation from the land surface, reducing soil temperature fluctuations (*Marliah*, 2011). Mulch can be divided into two, namely organic mulch and inorganic mulch (*Helyanto*, 2015). Mulches increase soil temperature, delay soil moisture loss, and check weed growth, which are the key factors contributing to production (*Ramakrishna et al.*, 2006; *Bucki and Siwek*, 2019). Coloured plastic mulches affect soil temperature and plant growth (*Ibarra-Jiménez et al.*, 2011; *Torres-Olivar et al.*, 2016). Plastic mulching could significantly increase crop yield and water use efficiency (*Gao et al.*, 2019). The efficiency of water use of plastic mulching was significantly higher than that of straw mulching (*Li et al.*, 2018).

Silver metallic plastic mulch is a plastic mulch that has two different surfaces (*Cahyono*, *2005*). Plastic mulch can also affect the use of sunlight. The reflected light from plastic mulch will have an impact on the process of photosynthesis because all sides of the leaf are evenly exposed to sunlight (*Darmawan et al.*, *2014*). The use of silver metallic plastic mulch gives the best effect on all parameters observed because of the colour of silver mulch; this type can reflect light that can be useful in the photosynthesis process so that more carbohydrates are formed (*Sudjianto and Krestiani*, *2009*). The difference in soil temperature between treatments without mulch and straw mulch in the morning was not different, but silver metallic plastic mulch showed higher soil temperatures (*Hamdani*, *2009*). High soil temperature can reduce humidity around plants so it can inhibit the emergence of diseases caused by bacteria (*Kusuma and Zuhro*, *2015*).

The creation of agricultural equipment and machinery is a basic step in the realization of efficiency and increasing agricultural productivity and quality. Agriculture mechanization aims to improve land and labour efficiency, save energy and resources (seeds, fertilizer and water, and equipment) to increase the effectiveness, productivity, and quality of agricultural products, reduce the workload of farmers, and increase farmer income and welfare (*Cebro and Sitorus*, 2019; *Sitorus et al.*, 2018; *Bulan et al.*, 2019; *Sitorus et al.*, 2019). Therefore, *Harahap et al.* (2020), have designed a mulch plastic punching machine to make it easier for farmers. They no longer have to manually dig the soil mulch. It has sizes of 100 $\times$ 80 $\times$ 60 cm^3. The initial design of a mulch plastic perforating machine used a sprocket transmission system that had 15 serrations. The results of the percentage of plastic mulch perforation using 15 tooth sprockets are 50%. The results are still low and further research needs to be done to obtain a higher percentage of the initial design of the plastic mulch perforating machine.

In addition, *Khazimov et al.* (2018), developed dual-action equipment for mulching soils and planting vegetable seedlings pulled by a four-wheeled tractor. The capacity of this machine can reach 0.4 ha/day or 271 seedlings/min with a speed of more than 2 km/h. Also, *Lawrence et al.* (2007), developed a dibbling machine for plastic mulch using a pneumatic method driven by a tractor's hydraulic system from a 4-wheeled tractor. This equipment has outstanding performance, but unfortunately, it will not be appropriate with aspects of land conditions and its economy if applied in Indonesia.

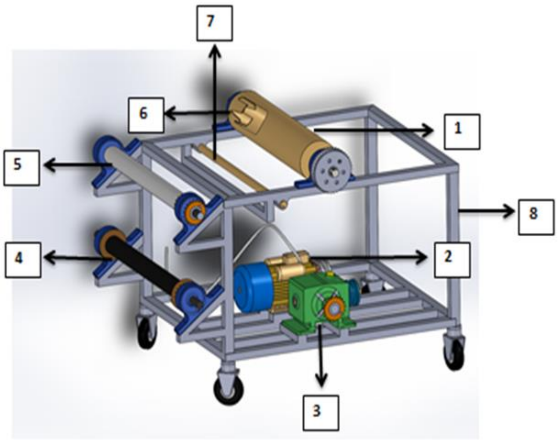
Hence, two additional speed variations were given in this study to obtain a higher percentage of perforated plastic mulch for small-scale perforation machinery. Each speed was obtained by giving variations in the size of the sprocket on different engine transmissions. This study uses a variation of a sprocket that has 36 serrations and a sprocket that has 42 serrations. The sprocket that has 36 serrations found that the rotational speed of the eye is 29 rpm and a sprocket that has 42 serrations is 25 rpm. Each sprocket was given three repetitions to see the results of the percentage of mulch plastic perforated by the holes punched.

MATERIAL AND METHODS

Plastic mulch hole puncher machine

This research was carried out at the UPTD Mekanisasi Pertanian in Indrapuri, Department of Agriculture, Aceh Besar Regency, Indonesia. Equipment and materials in this research are mulch plastic perforator, stopwatch, hand digital tachometer, clamp meter, mechanical devices, stationery supplies, and mulch plastic. The research began by studying the mechanism of action of a mulch plastic perforator. The next step is to give a variation of the sprocket in the plastic mulch hole transmission system to obtain three variations of speed. Speed measurements are carried out using a tachometer in the maker of the hole and are found at three different speeds. Each speed treatment was carried out three repetitions of work using 5 m of plastic mulch in each repetition. Of the three treatment speeds result two perforation criteria, namely, the perfect and partial holes. The measurement technique of electric motor power is to measure the available current and amperage of an electric motor using a clamp meter. Three treatments were measured for electric motor power at three different variations in the speed of the holes punched. Measurement of amperage on an electric motor is measured by clamping meter on the electric motor cable until a number appears on the digital screen.

The working mechanism of the plastic mulch hole-making machine carried out in this test starts from the initial roll of mulch paired through the clamp shaft. After that, the plastic mulch is put into the hole puncher roll. In the holes, the puncher roll occurs, the plastic mulch hole perforation process occurs. In the next step, the mulch plastic returns to the clamp shaft and goes to the pulling roll. This towing roll rolls back the hollow plastic mulch. The pinch shaft is used to suppress the mulch because it is easier to perforate. The description of the plastic mulch hole puncher machine designed by *Harahap et al.* (2020) is shown in Figure 1. The previous perforating machines were optimized for their performance in this study.



1-Hole puncher roll
2-Electric Motor
3-Gear box
4-Plastic mulch initial rollers
5-Plastic mulch rolling roll
6-Hole puncher blade
7-Plastic mulch clamp shaft
8-Main framework

Fig. 1 – Isometric of plastic mulch hole puncher machine

Determination of hole puncher speed

The effect of variations in rotational speed was investigated using a chain-sprocket transmission system. The sprocket that receives power from the engine has three variations in the number of gears. From the variations in the number of serrations on the sprocket, three different velocity eye holes are found. This speed determination aims to obtain the optimal rotational speed for the eye holes. Each speed is 25 rpm, 29 rpm, and 70 rpm. All speeds are obtained from a variation of the sprocket. First, a rotational speed of 25 rpm uses a sprocket that has the greatest number of serrations (42 serrations). It follows by 29 rpm and 70 rpm; they have 35 and 15 serrations. Figure 2 shows the transmission of the sprocket with a different number of serrations.

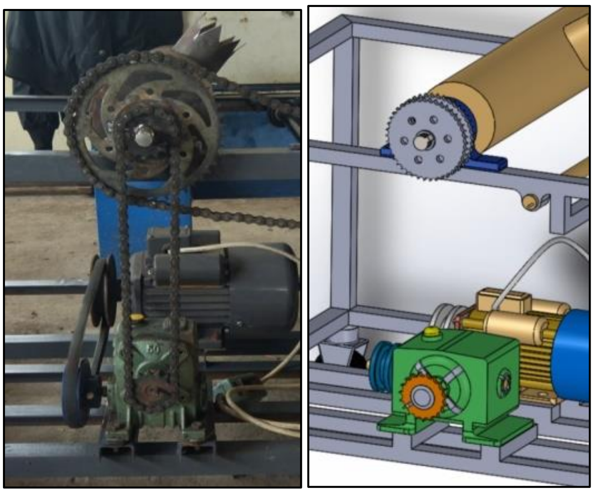


Fig. 2 – The transmission in the machine

RESULTS

Performance of plastic mulch hole puncher machine

Based on the results of the plastic mulch perforation test in the field, the plastic mulch perforation machine conducted by the study was able to perforate the plastic mulch with two quality results, namely a perfectly perforated and partially perforated plastic mulch. Plastic mulch holes puncher blades have been able to perforate flexible plastic mulch according to the research by *Shrefler and Brandenberger* (2014). Plastic mulch is shown to be a low-density polyethylene produced by the process of ethylene polymerization by using very high pressure. It requires a sharp knife to perforate plastic mulch.

Table 1 shows that the results of perfect perforation using 25 rpm have the lowest percentage of perfect perforation, which is equal to 9.3%. While the highest yield is obtained using 29 rpm, namely 86%. Using 29 rpm is said to be the best treatment because it produces the highest percentage of perfect holes. Meanwhile, the spaces between the holes found in the three treatments met the requirements for the planting space of chili. They are not less than 50 cm × 50 cm, but also not more than 65 cm × 65 cm. Spacing patterns must be considered because they can affect the level of competition between plants in terms of water, nutrients, and sunlight (*Hatta*, 2011). The optimal planting distance will provide good growth so that plants can use more sunlight and nutrients (*Sohel et al.*, *2009*).

Table 1

Percentage of perfectly perforated plastic mulch

Rotational speed (rpm)	Total holes	Total perfect holes	Duration (s)	Space between the holes (cm)
25	42	4	50	60
29	42	36	35	60
70	48	24	10	50

Table 2 shows that the average percentage value of partially perforated plastic mulch using 29 rpm is the lowest of the three treatments. Its percentage value is only 14%. The 29 rpm perforation velocity can be sure to be in normal speed when perforating the plastic mulch, so this speed is very suitable to be used. While using 70 rpm speed resulted in 50%, and the highest average percentage of partial perforation was found using 25 rpm, which was 90.6%. Based on the test results, no part of the mulch plastic is perforated even at low speed. The sharpness of the perforated blades of plastic mulch greatly influences the perforation process as in the research on the performance of the garbage chopping machine that has been carried out by *Juardin, (2017)*. The blade is cut by slicing from the base to the tip and may not all meet the rubbish field, and the blade has a tenuous gap, and the sharpness of the blade is still not good. The narrow gap distances are adjusted to improve the blade and are modified to become an edge crusher-type blade.

Table 2

Percentage of partially perforated plastic mulch

Rotational speed (rpm)	Total holes	Total partial holes	Duration (s)	Space between the holes (cm)
25	42	38	50	60
29	42	6	35	60
70	48	24	10	50

Machine capacity of plastic mulch hole puncher machine

The highest hole puncher working capacity is using 70 rpm, which is 576 holes/hr, and the least is using 25 rpm, which is 100 holes/hr. It can be supposed that increasing rotational speed will increase machine capacity. The comparison graph of the working capacity of the hole puncher can be seen in Figure 3. Based on research conducted by *Kharisma* (2014), on the disc mill machine, the higher the value of the rotation speed of the machine used, the longer the starch time successfully extracted is. Rotational speed affects the size and fineness of the particles. This has similarities in this study, namely the higher the speed of the hole puncher, the higher the results of the capacity of the hole puncher, and the speed of the hole puncher also affects the hole perforation produced (Figure 3). The faster the hole puncher rotation, the more holes are produced.

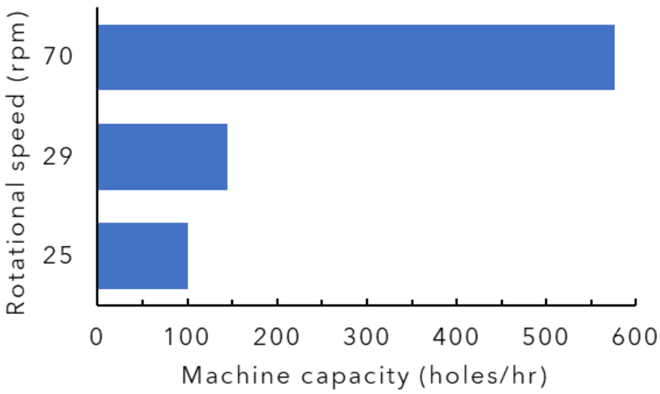


Fig. 3 – Work capacity of hole puncher machine

Correlation of rotation speed with total number of holes

The results of the rotational speed of the engine sprocket and the total plastic perforation of the mulch are shown in Figure 4. It is known that the results of mulch plastic perforation have a positive relationship with the rotational speed of the sprocket by means of a polynomial equation. Thus, the determination value of the graph above shows that the value of mulch punching results has a very close relationship with the rotational speed of the sprocket.

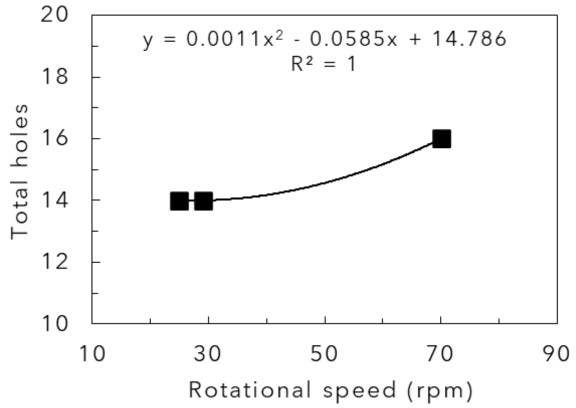


Fig. 4 – Observation results of engine sprocket rotation speed and plastic mulch punching results

Machine power consumption

Based on Figure 5 is performed the comparison of electric motor power requirements above; the electric motor power requirements using 25 rpm is 986.92 watts, then using 29 rpm is 1076 watts and using 70 rpm is 1516 watts. The highest electrical power requirement is at 70 rpm and the lowest is at 25 rpm. There are differences in electrical power requirements due to differences in the speed of the hole puncher. The higher the turning speed of the hole puncher, the higher the electric power needed.

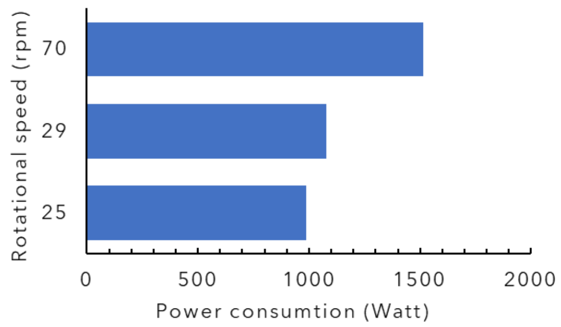


Fig. 5 – Comparison graph of electric motor power requirements

CONCLUSIONS

The increasing performance of the plastic mulch punching machine has been tested and presented in this study. Of the three treatments, the variation in speed on the mulch plastic perforating machine can provide a perforation with the criteria for perfect perforation and partial perforation. The engine sprocket can meet the optimal rotation speed for plastic mulch perforations. In this study, the optimal speed was found using 29 rpm because it has a high percentage of perfect perforation. The higher the speed of the engine sprockets, the more holes are produced by the machine. Most holes were produced using 70 rpm, namely up to 16 holes per 5 meters of mulch plastic. The highest percentage of perfect perforation is in a speed treatment of 29 rpm that is 86% and the lowest is in treatment of a speed of 25 rpm that is 9.3%. The coefficient determination between the rotational speed and machine performance positively correlates with the polynomial equation. The mulch plastic perforating machine that is used still has the disadvantages that there are parts of the mulch plastic that cannot be perforated as a whole, and the machine should be able to use other punching methods to improve the results of the mulch plastic perforation.

REFERENCES

[1] Bucki, P., Siwek P. (2019). Organic and non-organic mulches–impact on environmental conditions, yield, and quality of Cucurbitaceae. *Folia Horticulturae*, 31(1). 129-145.

[2] Bulan, R., Yasar M., Nata Y., Sitorus A. (2019). Design and construction of chopper machine AE02-type for oil palm frond. *INMATEH - Agricultural Engineering*, 57(1). 165-172.

[3] Cahyono, B. (2005). *Kacang Panjang (Teknik Budidaya dan Analisis Usaha Tani)*. *CV. Aneka Ilmu. Semarang. dengan Penambahan Effective Microorganism*, 10. 77-87.

[4] Cebro, I. S., Sitorus A. (2019). Performance evaluation of a hand tractor to climbing sloping land. *International Journal of Scientific and Technology Research*, 8(7). 781-785.

[5] Darmawan, I. G. P., Nyana I. D. N., Gunadi I. G. A. (2014). *Pengaruh penggunaan mulsa plastik terhadap hasil tanaman cabai rawit (Capsicum frutescens L.) di luar musim di Desa Kerta*. *Jurnal Agroekoteknologi Tropika*, 3(3). 148-157.

[6] Gao, H., Yan C., Liu Q., Ding W., Chen B., Li Z. (2019). Effects of plastic mulching and plastic residue on agricultural production: A meta-analysis. *Science of the Total Environment*, 651. 484-492.

[7] Hamdani, J. S. (2009). *Pengaruh jenis mulsa terhadap pertumbuhan dan hasil tiga kultivar kentang (Solanum tuberosum L.) yang ditanam di dataran medium*. *Jurnal Agronomi Indonesia*, 37(1).

[8] Harahap, A., Syafriandi S., Mustaqimah M., Afriadi A. (2020). *Rancang Bangun Mesin Pelubang Plastik Mulsa*. *Jurnal Ilmiah Teknologi Pertanian Agrotechno*, 5(1). 14-19.

[9] Hatta, M. (2011). *Pengaruh tipe jarak tanam terhadap anakan, komponen hasil, dan hasil dua varietas padi pada metode SRI*. *Jurnal Floratek*, 6(2). 104-113.

[10] Helyanto, J. (2015). "*Pengaruh sistem olah tanah dan pemberian mulsa bagas pada lahan tebu PT. GMP ratoon ke-3 terhadap populasi dan biomassa cacing tanah serta populasi dan keanekaragaman mesofauna tanah*." In.: Skripsi

[11] Ibarra-Jiménez, L., Lira-Saldivar R. H., Valdez-Aguilar L. A., Lozano-Del Río J. (2011). Colored plastic mulches affect soil temperature and tuber production of potato. *Acta Agriculturae Scandinavica, Section B-Soil & Plant Science*, 61(4). 365-371.

[12] Kharisma, N. (2014). "*Pengaruh Kecepatan Putar (RPM) Disc Mill Terhadap Keseragaman Ukuran Butiran Gula Semut*." In.: Skripsi. Universitas Lampung. Lampung

[13] Khazimov, Z. M., Bora G. C., Khazimov K. M., Khazimov M. Z., Ultanova I. B., Niyazbayev A. K. (2018). Development of a dual action planting and mulching machine for vegetable seedlings. *Engineering in Agriculture, Environment and Food*, 11(2). 74-78.

[14] Kusuma, A., Zuhro M. (2015). *Pengaruh varietas dan ketebalan mulsa jerami padi pada pertumbuhan dan hasil tanaman tomat (Lycopersicum esculentum Mill.)*. *J. Agrotechbiz*, 2(1). 1-10.

[15] Lawrence, M. J., Buckmaster D. R., Lamont W. J. (2007). A pneumatic dibbling machine for plastic mulch. *Applied Engineering in Agriculture*, 23(4). 419-424.

[16] Li, Q., Li H., Zhang L., Zhang S., Chen Y. (2018). Mulching improves yield and water-use efficiency of potato cropping in China: A meta-analysis. *Field crops research*, 221. 50-60.

[17] Marliah, A. (2011). *Pengaruh pemberian pupuk organik dan jenis mulsa organik terhadap pertumbuhan dan hasil kedelai (Glycine max (L.) Merrill)*. *Jurnal Floratek*, 6(2). 192-201.

[18] Pribadi, G. Y., Roviq M., Wardiyati T. (2014). '*Pertumbuhan dan produktivitas sawi pak choy (Brasica rapa L.) pada umur transplanting dan pemberian mulsa organik*', Brawijaya University

[19] Ramakrishna, A., Tam H.M., Wani S.P., Long T. D. (2006). Effect of mulch on soil temperature, moisture, weed infestation and yield of groundnut in northern Vietnam. *Field crops research*, 95(2-3). 115-125.

[20] Shrefler, J., Brandenberger L. (2014). "Use of plastic mulch and row covers in vegetable production." In.: Oklahoma Cooperative Extension Service

[21] Sitorus, A., Fauzi A., Ramadhan G., Hasan A. R., Karyadi A. (2019). "Conceptual design of harvesters knife for Chinese spinach (ipomoea reptans Poir.): CAD approach." In *Proceedings - 2018 4th International Conference on Computing, Engineering, and Design, ICCED 2018*, 7-12.

[22] Sitorus, A., Hermawan W., Setiawan R. P. A. (2018). "Design and performance of combine corn transplanter powered by hand tractor." In *3rd International Conference on Computing, Engineering, and Design, ICCED 2017*, 1-5.

[23] Sohel, M., Siddique M., Asaduzzaman M., Alam M., Karim M. (2009). *Varietal performance of transplant aman rice under different hill densities*. *Bangladesh Journal of Agricultural Research*, 34(1). 33-39.

[24] Sudjianto, U., Krestiani V. (2009). *Studi pemulsaan dan dosis NPK pada hasil buah melon (Cucumis melo L)*. *Jurnal Sains dan Teknologi*, 2(2). 1-7.

[25] Tinambunan, E., Setyobudi L., Suryanto A. (2014). '*Penggunaan Beberapa Jenis Mulsa Terhadap Produksi Baby Wortel (Daucus carota L.) Varietas Hibrida*', Brawijaya University

[26] Torres-Olivar, V., Valdez-Aguilar L. A., Cárdenas-Flores A., Lira-Saldivar H., Hernández-Suárez M., Ibarra-Jiménez L. (2016). Effect of colored plastic mulch on growth, yield and nutrient status in cucumber under shade house and open field conditions. *Journal of Plant Nutrition*, 39(14). 2144-2152.

[27] Utomo, R. R., Agus Suryanto S. (2013). *Penggunaan mulsa dan umbi bibit (G4) pada tanaman kentang (solanum tuberosum l.) varietas granola*. *Jurnal Produksi Tanaman*, 1(1).