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INCREASED GROWTH AND YIELD OF LOCAL SUMATRAN RED CHILI VARIETIES BY GIVING HUMIC ACID UNDER LIMITED SOIL WATER AVAILIBILITY

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ABSTRACT
Research aimed at increasing the production and productivity of various Local Sumatran red chili varieties under limited soil water availability using humic acid was carried out from May to October 2022, at the Teaching and Research Farm, Faculty of Agriculture, Jambi University (35 m above sea level). The research used a Randomized Block Design with a factorial pattern and three replications. The first factor is the dose of humic acid: 0 $kgha^{-1}$; 5 $kgha^{-1}$; and 10 $kgha^{-1}$, and the second factor is Local Sumatran red chili varieties: Vitra; Loker Telun Berasap; and Awe Aceh. The research results showed that various red chili varieties gave the same response to the application of humic acid under limited soil water availability of 75% FC. Humic acid can increase the growth and yield of red chilies, and a dose of 10 $kgha^{-1}$ provides the best growth and yields for red chilies. The Loker variety provides better plant height, number of branches, crown diameter, and fruit number than other varieties, but produces the lowest fruit weight. Meanwhile, the Vitra and Awe varieties, although their growth is relatively not as good as Loker, are capable of producing high fruit weights. The Loker variety, which is a red chili variety from the Kerinci highlands, has not been able to adapt well to the lowlands of Jambi. One effort to increase the ability of the Loker variety to produce better quality fruit is to combine humic acid with liquid fertilizer during fruit enlargement.

KEY WORDS
Capsicum annuum, drought, dryland, production, productivity.

Red chili (*Capsicum annuum* L.) is a vegetable commodity that humans need as a spice that can provide a spicy taste to various dishes; some people even use red chili as medicine. Maharijaya and Syukur (2014) stated that demand for red chilies is increasing, especially at certain times such as Ramadhan, Syawal, Christmas, and New Year. The export opportunity for red chili commodities, especially curly red chilies, is also very high, both for fresh consumption and for drying and making powder, especially for the Middle East and European markets.

Meeting the need for red chilies for the future is hampered by the increasing population and global climate change. The impacts of global climate change include changes in rainfall patterns and intensity, as well as the increasingly frequent occurrence of extreme climate phenomena such as droughts and floods (Ayyogari et al., 2014). This has an impact on increasing the production and productivity of red chilies because red chilies are a plant that is very sensitive to water stress which is triggered by excess or lack of water. Various research results show that a decrease in water availability or drought can cause stress to red chili plants, thereby reducing growth and yield (Mardani et al., 2017; Ichwan et al., 2020).

Efforts that can be made to maintain the production and productivity of red chili plants in drought conditions are by adding organic material to the soil. Organic matter can increase the soil's ability to hold water, thereby reducing the impact of stress on plants. Humic acid is an organic material that is can improve soil fertility by increasing the soil's ability to hold water, increasing the availability of nutrients, increasing plant growth and development, and reducing the detrimental effects of stress through various mechanisms in plants and soil (Moraditochaee, 2012).

The research results showed that the application of humic acid increased the growth and yield of green beans at various soil water availabilities. Reducing soil water availability from 100% to 60% reduces plant growth and yield, meanwhile, the use of humic acid will increase growth and yield with the higher dose of humic acid given. Providing 15 to 45 kg of humic acid per hectare at various levels of soil water availability (100%, 80%, and 60%) increases plant growth and yield (Al-Shareef et al., 2018).

Khorasaninejad et al. (2018) stated that to get good growth of *E.purperea* plants (a type of herbal plant), humic acid needs to reduce stress due to drought. The results showed that drought stress reduced chlorophyll, carotenoids, and the relative water content of plants, but increased ion leakage, the percentage of burnt leaves, and the proline content of plants. Furthermore, giving humic acid to two melon varieties increases the fresh weight and dry weight of shoots, as well as plant leaf area under drought-stress conditions. Humic acid stimulates the accumulation of K and Ca ions, chlorophyll, and the activity of antioxidant enzymes (superoxide dismutase-SOD, catalase-CAT, and glutathione reductase-GR) (Kiran, et al, 2019), thereby increasing melon tolerance to drought stress.

The various research results above provide information that humic acid can increase plant growth and yield in drought conditions, indirectly through improving the physical, chemical, and biological properties of the soil, and directly by increasing plant metabolism in conditions of water shortage or drought, however, the various humic acids used vary in concentration, dosage and method of administration, which affects the effectiveness of the humic acid given. Apart from that, the efficacy of humic acid is also influenced by the type of plant and variety used. The use of local red chili varieties, including Vitra, Loker Telun Berasap, and Awe Aceh, is one of the efforts to increase the production and productivity of red chilies in conditions of limited water availability. This is because various local red chili varieties, apart from having high yield potential, also have quite broad agro-climatic adaptability, as well as various other specific advantages. The use of humic acid is expected to increase the growth and yield of local Sumatran red chilies and increase their adaptability to limited water availability conditions. Apart from that, the use of local varieties is also an effort to preserve germplasm in the context of plant breeding and protecting genetic resources.

Information about the response of various local Sumatran red chili varieties to the application of humic acid in drought conditions in order to increase red chili production and productivity is still very limited. Therefore, research on the response of local Sumatran varieties of red chilies to humic acid in drought-stressed conditions is very important to carry out, especially regarding the dosage required for red chilies which can increase growth and yield in drought-stressed conditions, so that they are still able to grow and produce. It is hoped that from this research, local Sumatran red chili varieties will be obtained that are responsive to the application of humic acid, and increase the production and productivity of red chilies in drought conditions, as well as preserving the germplasm of local Sumatran red chili varieties, and their development in all regions in Indonesia in conditions of water availability limited.

METHODS OF RESEARCH

The research was carried out at the Teaching and Research Farm, Faculty of Agriculture, University Jambi, starting from April 2022 to October 2022. The research used a Randomized Block Design with two factors. The first factor is various doses of humic acid, namely 0 kgha^{-1}; 5 kgha$^{-1;}$ and 10 kgha^{-1}, while the second factor is local Sumatran red chili varieties consisting of Vitra; Loker Telun Berasap; and Awe Aceh.

Chili seedlings that are ten days old and have three to four leaves are moved from the nursery and planted in polybags measuring 4 cm x 10 cm which have been filled with soil, sand, and compost in a ratio of 2:1:1. After the seeds are three weeks in the nursery or when they have six leaves, the seedlings were transferred to polybags measuring 25 cm x 40 cm and filled with a mixture of soil, manure, and sand (Ichwan et al., 2021) with a media weight of 7 kg and a media height of less more than 25 cm. Limited soil water availability at 75% Field Capacity (FC) begins when the plants are moved from the nursery or when the seedlings are 0 weeks after planting (WAP) until harvest.

The application of humic acid is carried out simultaneously with the application of basic fertilizer NPK, which is as much as 700 kg ha^{-1} and is given by mixing humic acid with NPK fertilizer. Follow-up fertilizer NPK (16:16:16) is provided by pouring it when the plants are 6 WAP with a concentration of $2gL^{-1}$ of 4000 Lha^{-1} per application and a volume of 100 ml per plant. Maintenance carried out includes watering, weeding, and pathogen control. Harvesting is carried out from 12 WAP to 16 WAP (during the first flowering period), with the color criteria for chili fruit being 80% of each fruit is red.

Observations were made when the plants were 10 WAP during the fruit formation period, by observing plant height, number of branches, and crown diameter. The number of fruit, fruit weight per plant, and weight per fruit were observed at harvest, while the chlorophyll content of plants and the relative water content at plants aged 10 WAP. The data was analyzed with analysis of variance and then continued with the LSD test.

RESULTS AND DISCUSSION

The results of variance analysis showed that there was no significant interaction between humic acid and chili variety on the height of red chili plants aged 10 WAP (fruit ripening phase), but humic acid and variety alone had a significant effect on red chili plant height. Increasing the dose of humic acid increased the height of red chilies aged 10 WAP, meanwhile, the Loker variety of red chili had a higher plant height and was significantly different from other red chili varieties (Table 1).

Table 1 – Height of red chili plants at various humic acid doses and varieties aged 10 WAP under limited soil water availability

Humic acid ($kgha^{-1}$)	Varieties			
	Vitra	Loker	Awe	Average
0	94,67	110,33	94,67	99,88a
5	103,00	119,33	95,00	105,77b
10	110,00	129,00	97,50	112,16c
Average	102,55b	119,55c	95,72a	

Note: Numbers followed by the same letter in the same column and row are not significantly different according to the LSD test α = 5%.

The number of red chili branches aged 10 WAP was not significantly influenced by the interaction between the dose of humic acid and the red chili variety. Still, humic acid and variety alone had a significant effect on the number of red chili branches. The Loker variety is more responsive to the application of humic acid. Increasing the dose of humic acid to 10 $kgha^{-1}$ increased the number of red chili branches and was different from without humic acid. Compared with the Loker and Vitra varieties, the Awe variety has the lowest number of branches (Table 2).

Table 2 – The number of red chili branches at various humic acid doses and varieties aged 10 WAP under limited soil water availability

Humic acid ($kgha^{-1}$)	Varieties			
	Vitra	Loker	Awe	Average
0	252,33	345,00	245,33	280,88a
5	324,00	377,33	317,67	339,66bc
10	353,67	429,00	257,33	346,66c
Average	310b	383,77c	273,44a	

Note: Numbers followed by the same letter in the same column and row are not significantly different according to the LSD test α = 5%.

The interaction between humic acid and red chili varieties did not have a significant effect on plant crown diameter, however, humic acid had a significant effect, and likewise, variety had a significant effect on red chili crown diameter. The application of humic acid increases the crown diameter of various red chili varieties. The highest crown diameter was obtained when applying 10 $kgha^{-1}$ of humic acid and was significantly different from 5 $kgha^{-1}$ and 0 kgha-1 of humic acid. The Loker variety gave significantly different crown diameters to Vitra and Awe, while Vitra and Awe gave the same crown diameter (Table 3).

Table 3 – The crown diameter of red chili at various humic acid doses and varieties under limited soil water availability

Humic acid ($kgha^{-1}$)	Varieties			Average
	Vitra	Loker	Awe	
0	75,67	81,00	80,00	78,88a
5	85,00	95,33	84,33	88,22b
10	87,67	105,00	89,00	93,88c
Average	82,77a	93,78b	84,44a	

Note: Numbers followed by the same letter in the same column and row are not significantly different according to the LSD test α = 5%.

The number of red chili fruit is influenced by the interaction between humic acid and variety. The Loker variety produced a higher number of fruits at various doses of humic acid, while the Awe variety produced the lowest number of fruits compared to other varieties at various doses of humic acid given. Increasing the dose of humic acid increased the number of red chili fruits in each variety. A humic acid dose of 10 tons ha-1 produced the highest number of fruits for each variety and was significantly different from without humic acid (Table 4).

Table 4 – Interaction of humic acid and red chili varieties on the number of red chili fruit under limited soil water availability

Humic acid (kgha-1)	Varieties			Average
	Vitra	Loker	Awe	
0	57,50aA	74,00aB	55,50aA	62,33
5	65,17abA	97,00B	61,33aA	74,50
10	73,17bA	114,67cB	69,67bA	85,83
Average	65,28	95,22	62,17	

Note: Numbers followed by the same lowercase letter in the same column and the same uppercase letter in the same row are not significantly different according to the LSD test α = 5%.

Red chili fruit weight was not influenced by the interaction between humic acid and variety, but a significant effect occurred for humic acid and variety alone. The Loker variety has the lowest fruit weight compared to other varieties, even though the number of fruits is greater. Meanwhile, increasing the dose of humic acid was still able to increase the weight of red chili fruit, and the highest fruit weight was obtained at a humic acid of 10 $kgha^{-1}$ (Table 5).

Table 5 – Weight of red chili fruit at various humic acid doses and varieties aged 10 WAP under limited soil water availability

Humic acid (kgha-1)	Varieties			Average
	Vitra	Loker	Awe	
0	246,85	175,23	231,25	217,77a
5	270,38	243,53	268,45	260,78b
10	310,00	298,82	326,98	311,93c
Average	275,74b	239,19a	275,56b	

Note: Numbers followed by the same letter in the same column and row are not significantly different according to the LSD test α = 5%.

Fruit quality observed included fruit length, fruit diameter, and weight per fruit. Increasing the dose of humic acid can improve the quality of red chili fruit. A humic acid dose of 10 $kgha^{-1}$ gave the highest fruit length, fruit diameter, and weight per fruit for red chilies and was different from other doses, except for weight per fruit, where the humic acid dose of 5 $kgha^{-1}$ was not different from 10 $kgha^{-1}$ (Table 6).

Table 6 – Fruit length, fruit diameter and weight per fruit of red chilies at various humic acid doses under limited soil water availability

Humic acid (kgha^{-1})	Fruit length (cm)	Fruit diameter (cm)	Weight per fruit (g)
0	14,09a	1,29a	3,57a
5	14,66b	1,38b	3,71ab
10	15,14c	1,52c	3,86b

Note: Numbers followed by the same letter in the same column are not significantly different according to the LSD test α = 5%.

The quality of red chili fruit in the form of fruit length, fruit diameter, and weight per fruit was good in the Awe and Vitra varieties (Table 7).

Table 7 – Fruit length, fruit diameter and weight per fruit of red chilies at various varieties of red chili under limited soil water availability

Varieties	Fruit length (cm)	Fruit diameter (cm)	Weight per fruit (g)
Vitra	15,28bc	1,59bc	4,23bc
Loker	13,12a	1,10a	2,50a
Awe	15,49c	1,52c	4,42c

Note: Numbers followed by the same letter in the same column are not significantly different according to the LSD test α = 5%.

The relative water content of red chilies was not significantly influenced by various doses of humic acid and varieties. Furthermore, the results of the analysis of red chili chlorophyll at various doses of humic acid and in various varieties showed that increasing the dose of humic acid increased the total chlorophyll content of red chilies, and a humic acid dose of 10 kgha^{-1} gave the highest total chlorophyll, while the Loker variety produced the highest chlorophyll content followed by Awe varieties and then Vitra (Table 8).

Table 8 – Relative water content and total chlorophyll of red chilies at various humic acid doses and varieties aged 10 WAP under limited soil water availability

Parameter	Humic acid (kgha^{-1})			Varieties		
	0	5	10	Vitra	Loker	Awe
Relative water content (%)	84,24	85,39	85,91	86,70	85,11	86,02
Klorofil total (mgL^{-1})	1,17	1,44	1,62	1,23	1,99	1,67

The results showed that the interaction of humic acid and variety had no significant effect on all observed variables except the number of red chilies. This means that all varieties tested gave the same response to the application of humic acid under conditions of 75% field capacity. Humic acid 5 kgha^{-1} and 10 kgha^{-1} in water soil availability or drought conditions provides better growth and yield, compared to without giving humic acid (0 kgha^{-1}), as well as fruit quality in the form of fruit length, fruit diameter, and weight per fruit increased with increasing doses of humic acid given. These results show that humic acid can increase the water-holding capacity of soil (Lodhi et al., 2013) so that in conditions of soil water content of 75% FC plants can still grow and develop well. The relative water content of the red chili planting medium treated with humic acid showed that the water content was higher than that without humic acid (Table 8). According to Azevedo and Lea (2011) and Moraditochaee (2012), humic acid can reduce drought stress by regulating plant osmotic potential by maintaining water absorption and cell swelling, thereby minimizing the consequences of drought stress.

Red chilies that were given humic acid had higher height, number of branches, crown diameter, number of fruit, and fruit weight compared to those that were not given humic acid. The increase in plant growth and yield due to humic acid is also caused by humic acid being able to increase the nutrient content of plant media such as P, K, Ca, Mg, Fe, Zn, and Mn, except Cu (Ekin et al., 2019). Humic acid contains 40 – 60% C, 25 – 45% O_2, 2-5% N, and other inorganic elements 0.5–5% (Rupiasih, Vidyasagar, 2005), as well as 1-2% S, and 0-0.3 % P (Firda et al., 2016) thereby increasing the availability of elements in the soil solution.

The results of research on corn plants conducted by Hassan et al. (2019) also showed that giving humic acid significantly increased plant height, leaf area, and ear length by 11.69%, 24.89%, and 3.49% compared to not giving humic acid. Furthermore, the results of research conducted by Noroozisharaf and Kaviani (2018) on *Thyme vulgaris* L. plants showed that giving humic acid increased plant uptake of N, P, K, Mg, and Fe

Humic acid can improve soil structure, increase soil cation exchange capacity and soil buffer capacity, and increase the population of soil microbes including beneficial microorganisms (Nardi et al., 2002). Improving soil properties by applying humic acid changes the architecture and dynamics of plant root growth, increasing root size, branching, and greater density of root hairs, with a larger surface area (Canelass and Olivares, 2014). This will indirectly improve the ability of the roots to absorb soil mineral nutrients needed by plants for plant growth, which will increase the efficiency of photosynthesis, cell division, and development, thereby increasing the height and number of plant branches (Haghighi et al., 2011; Shahryari et al., 2011).

The results of chlorophyll analysis in red chilies showed that red chilies that were given humic acid had higher chlorophyll levels, and the highest chlorophyll levels were obtained at a humic acid dose of 10kgha^{-1} (1.62%). Increasing chlorophyll levels will increase the plant's ability to carry out the photosynthesis process, increase the carbohydrates produced, and plant growth and yield. Nardi et al. (2002) stated that humic acid can influence the photosynthesis process of plants, so plants given humic acid are better able to carry out the photosynthesis process. These results are in line with the research results of Haghighi et al. (2002) in lettuce plants, where the application of humic acid increased plant photosynthetic activity in line with increasing chlorophyll content and leaf mesophyll conductance.

The local varieties tested provided good growth and yields in soil water availability conditions, although the yields obtained in drought conditions were only around 35% of the potential yield of each variety. The Loker variety provides the best performance in terms of plant height, number of branches, crown diameter, and number of fruits per plant. However, the weight of the fruit produced is lower compared to the Vitra and Awe varieties. This is because the Loker variety is a red chili variety that was developed in the Kerinci highlands, so it does not have good adaptability in the lowlands, so the quality of the fruit produced (length, diameter, and weight per fruit) is not as good as those grown in the highlands. Meanwhile, the Vitra varieties from Bengkulu and Awe from Aceh are red chili varieties that can adapt well when planted in the lowlands, medium, and highlands. Even though the growth is not as good as the Loker variety, these two varieties have better fruit quality, so with a small number of fruit they can produce high fruit weight.

The fruit length of the Loker variety produced from this research is shorter than the description (13.12 cm from 15-18 cm), but the fruit diameter is better (1.10 cm from 0.8 cm), meanwhile for Vitra the fruit length is produced according to the variety description with better fruit diameter (1.59 cm from 1.0 cm).

To produce high fruit weight, it is necessary to increase the adaptability of the Loker variety when planted in the lowlands, by providing special treatment such as fertilizer which can improve the quality of the fruit. If this can be done, the Loker variety is very promising to be developed as a local Jambi variety which has high yield potential.

CONCLUSION

Various local Sumatran red chili varieties provide the same response to the administration of various doses of humic acid in limited soil water availability. Application of 10 kgha^{-1} of humic acid in limited soil water availability provides the best growth, yield, and quality of red chilies. The Vitra and Awe varieties of red chilies provide better results than the Loker variety in limited soil water availability. To increase the growth and yield of various local Sumatran red chili varieties in limited soil water availability, it is necessary to combine humic acid with liquid fertilizer containing high levels of P and K, which can increase plant generative growth and photosynthate translocation for fruit enlargement.

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