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### RESEARCH ARTICLE

#### FARMING INPUTS AND WATER STRESS IMPACT ON GROWTH AND YIELD OF GARLIC (*Allium sativum* L.) IN THE RAINFED HIGHLANDS OF EASTERN LOMBOK, INDONESIA

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#### Abstract

Garlic (*Allium sativum* L.) is a horticultural commodity of high economic value in Indonesia. West Nusa Tenggara (WNT) Province is one of the largest garlic producing regions in Indonesia with 45% to the national harvest area. Garlic is mostly grown in irrigated highlands; however domestic production is very limited and only supplies at most 5% of domestic demand. Currently, garlic farming is facing the problem of decreasing soil fertility, the use of high inputs of inorganic fertilizers, and excessive chemical pesticides. Therefore, it is beneficial to investigate garlic cultivation input packages that may reduce inputs and so lower production costs in rainfed highlands which are prospective areas for garlic. The input-saving packages investigated were reduced use of inorganic fertilizers and chemical pesticides; up to 50% from farmers' practices. The four applied input packages were P1 (farmers' existing practices) and reduced and modified input packages P2, P3 and P4. The experiment was conducted in the Sembalun Highlands (1200 m above sea level) of Eastern Lombok, WNT Province during the growing season of 2018 on 0.4 ha of rainfed land using a completely randomized block design. Parameters measured were agronomic performance and productivity. Results showed that there were no significant differences in the agronomic growth and productivity of garlic from the four input packages applied. However, the experiment had sub-optimal yield due to the early onset of the dry season because of climate change.

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#### Introduction:-

Garlic (*Allium sativum* L.) is a horticultural commodity of very high economic value (Aaron, 1996). Garlic is the 14<sup>th</sup> most important vegetable crop worldwide (FAO, 2011). It is the second most consumed plant of the *Allium* genus worldwide (FAO, 2018). Over the last 50 years, garlic production and acreage have increased about 200% with more than 1.5 million hectares in 2014 (FAO, 2018). As a medicinal plant, garlic has several bioactive compounds with nutritional and health benefits such as antibiotic and anticancer compounds as well as compounds for the treatment of metabolic, cardiovascular and respiratory system diseases (Najda *et al.*, 2016). Therefore, it is desirable to increase its consumption worldwide (Amagase *et al.*, 2001).

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Garlic is an especially important horticultural product in Indonesia because it is used as a cooking spice and for medicines and cosmetic ingredients (Hilman *et al.*, 1997). Garlic has several regional local names in Indonesia, such as *dason putih* (West Sumatera), *bawang bodas* (West Java), *bawang* (Central Java), *bhabang poote* (Madura), *kasuna* (Bali), *lasuna mawura* (North Sulawesi), *bawa badudo* (Ternate), and *bawa fiufer* (Papua) (Santoso, 2000). Garlic is usually cultivated in irrigated highlands (>1,000 m above sea level) where the weather is cooler than in the lowlands. The national annual demand of garlic in Indonesia is estimated at 500,000 tonnes but domestic production is only 20,000 tonnes (Centre for Statistical Bureau, 2015) resulting in imports of 480,000 tonnes (96% of demand). Many varieties of garlic are found in the local markets and in supermarkets. Imported varieties come from China, Egypt and India, while local varieties are *Sangga Sembalun* (white), *Sangga Sembalun* (purple), *Sangga Nunggal*, *Lumbu Kuning*, *Lumbu Hijau* and *Ncuna Sambori* (Fitrotin and Hidayah, 2019).

The Sembalun Highlands in Eastern Lombok, West Nusa Tenggara Province are one of the garlic centers of Indonesia. From 1997 until 2017 garlic cultivation in the region declined as it is uncompetitive with the cheaper imported garlic. In the last few years, the cultivation of garlic was revived by the Indonesian government. One of the strategies to increase domestic production is to expand the growing areas into wet season production in rainfed highlands. The objectives of this research were to investigate agronomic performances and productivity of garlic crops (local *Sangga Sembalun* cultivar) based on different farming input packages in the rainfed highlands of Eastern Lombok, Indonesia.

## Materials and Methods: -

### Materials

Materials used were the local garlic variety (*Sangga Sembalun* cultivar), local cow manure, dolomite, fertilizers (NPK, SP-36, ZA, Urea, KCl), nitrite acid 20%, and pesticides. Implements were used were tractors, hoes, sprayers, weed removal tools, scales, and tarpaulins.

### Methods

A field experiment was conducted in the Sembalun Higlands (1200 m asl) in Eastern Lombok of Indonesia from February to June 2018 to investigate cultivation input packages on agronomic performance and yield of a local variety of garlic. The experimental design was a completely randomized block of four blocks. Each block consisted of four treatments: 1) Farmers' usual cultivation input package (P1); 2) Cultivation Input Package I (P2); 3) Cultivation Input Package II (P3); and 4) Cultivation Input Package III (P4). Therefore, there were sixteen plots in total. The experimental was 0.4 ha comprising four replication blocks of 0.1 ha each. The details of the cultivation input package are shown in Table 1. The experimental randomisation is shown in Table 2.

**Table 1:-** Cultivation input packages applied in field experiment during the growing season of 2018.

Inputs	Farmers' Existing Cultivation Input Package (P1)	Modified Cultivation Input Packages		
		(P2)	(P3)	(P4)
Dolomite (kg/ha)	0	1000	750	500
Cow manure (kg/ha)	3,000	10,000	7,500	5,000
NPK 16:16:16 (kg/ha)	500	400	300	200
SP-36 (kg/ha)	400	300	250	200
ZA (kg/ha)	400	300	250	200
KCl (kg/ha)	300	250	200	150
Pest and disease control	Existing technology (mixing pesticides as usual used by farmers)	Spraying pesticides based on rotation strategies	Spraying pesticides based on rotation strategies	Spraying pesticides based on rotation strategies

**Table 2:-** The experimental design and plot randomization in the field during the growing season of 2018

BLOCK			
I	II	III	IV
P3	P1	P4	P2

P1	P2	P3	P4
P4	P3	P2	P1
P2	P4	P1	P3

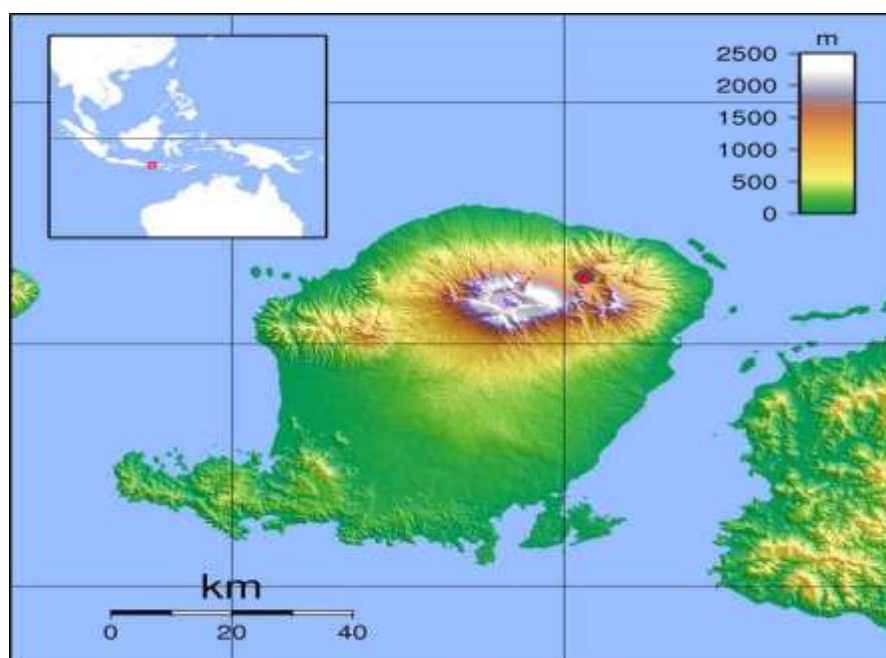
### Statistical Analysis

Data was analysed with SPSS version 12.0 using one-way ANOVA followed by least significant different (LSD) test at the 95% confident level ( $p < 0.05$ ).

## Results and Discussion:-

### General condition of the experimental site

The experimental site was a farmers' field with horticulture commodity cropping patterns; the sandy sand soil had a pH of 5.5. The location is a rainy season horticultural area in East Lombok Regency, categorised as a rainfed highland. The crop's water needs relied on rainfall. Soil moisture at sowing was suitable for planting garlic, but as the crop matured and approached harvest there was no rain resulting in water stress. The map of the experimental site is shown in Figure 1.

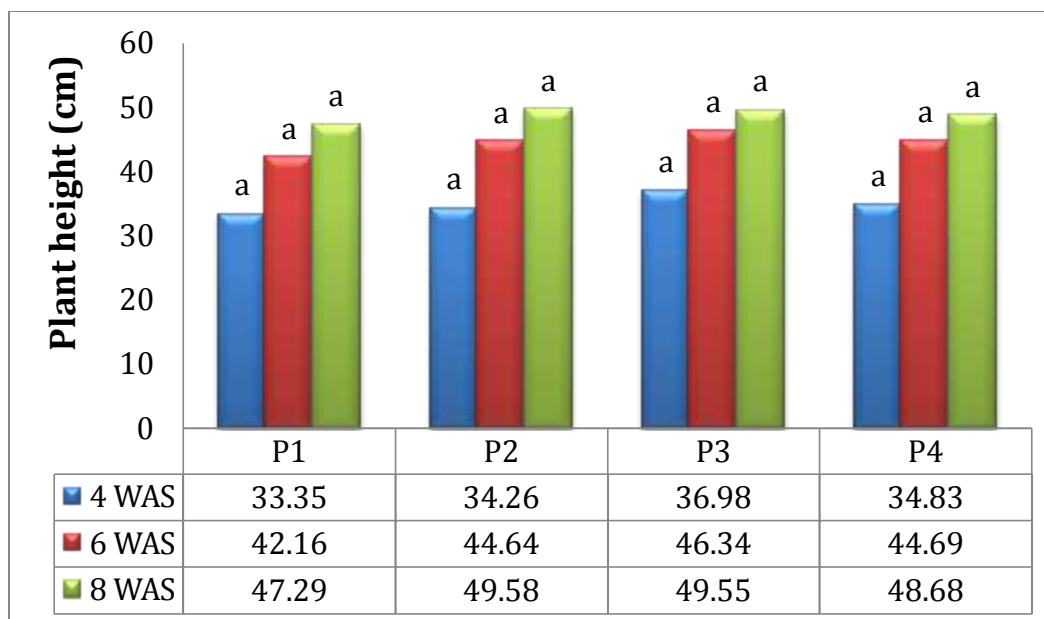


**Figure 1:-** Map of Lombok Island where the experimental site is in Sembalun highlands of East Lombok Regency with red dot sign on the upper right part of the island.

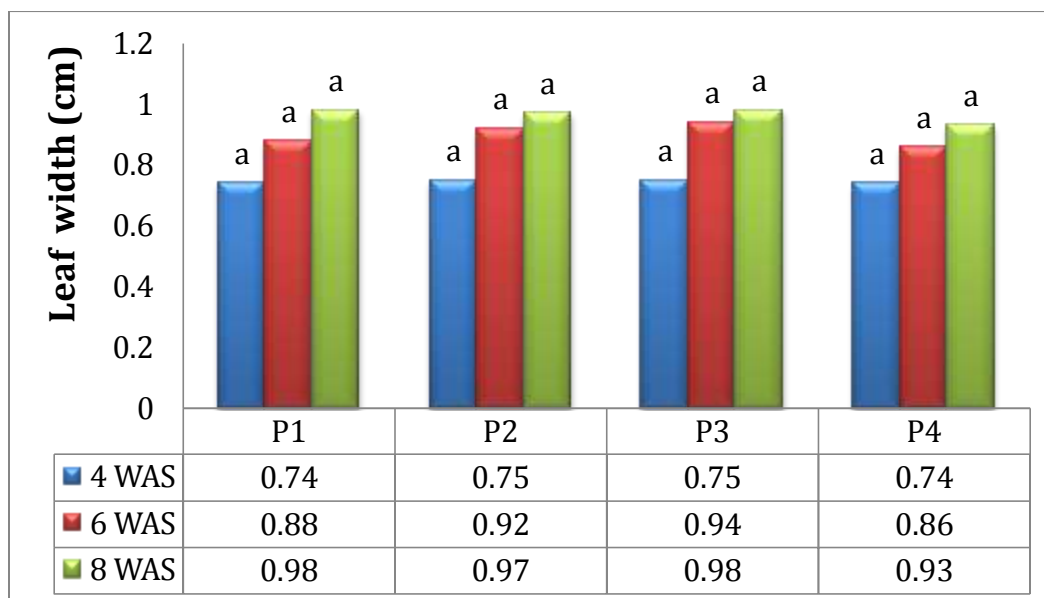
The soil type of the experimental site based on soil analysis in the Institute for Assessment of Agricultural Technology (IAAT) West Nusa Tenggara laboratory was sandy sand where sand was more dominant than silt and clay. The pH below 6 was ideal site for treatment of dolomite for increasing pH in order to make the soil more productive (Rochayati *et al.*, 1986).

### Vegetative growth

The vegetative growth of the garlic treatments was observed at 4, 6 and 8 weeks after sowing (WAS). Parameters measured were plant height and leaf width. Plant height and leaf width for each treatment are presented in Figures 2 and 3. Figure 2 shows the height of the treatments at 4, 6 and 8 WAS did not show any statistically significant difference. This shows that although P4 supplied the minimum input plant height was not significantly different from the higher input treatments. Figure 3 shows that there was also no significant difference in leaf width between treatments. Thus, the minimum cultivation input package (P4) produced the same leaf width as the other input package treatments.



**Figure 2:-** Plant height at 4, 6, and 8 weeks after sowing during the field experiment of various cultivation input packages in the Sembalun highlands in growing season 2018.



**Figure 3:-** Leaf width at 4, 6, and 8 weeks after sowing during the field experiment of various input packages in the Sembalun highlands in growing season 2018.

The vegetative growth of the garlic treatments during this field experiment in the rainfed highlands of Sembalun, Eastern Lombok were optimal during the vegetative phase with sowing on 17-18 February 2018 and there was still enough rainfall until the end of March 2018 where the crops were about 42-43 days old. There was no significant difference in growth of each cultivation input package as shown by plant height and leaf width. As an impact of climate change in 2018, the dry season occurred earlier from the beginning of April 2018 after which the treatments experienced water stress due to reduced rainfall. Water deficit seriously threatens crop productivity worldwide (Sánchez-Virosta and Sánchez-Gómez, 2019). The vegetative growth performances during field experiment is shown in Figure 4.



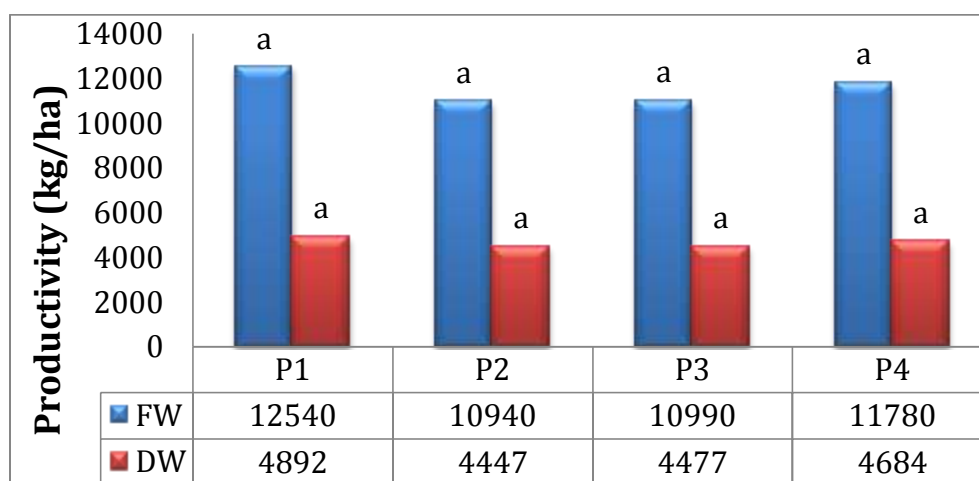


**Figure 4:-** Vegetative growth performances of garlic in the Sembalun highlands in growing season 2018.

#### Garlic yield

Garlic yield of four cultivation input packages during the field experiment in 2018 showed suboptimal yield due to the environmental factor of water availability. Rainfall was very low from the beginning of April 2018 until harvest. Data on garlic productivity, both fresh and dry weight (1 month after drying) is shown in Figure 5.

Figure 5 shows that garlic fresh weight was not significantly different for each cultivation input package. Likewise, dry weight after sun drying for one month showed no significantly difference. Although this yield was not optimal due to the early onset of the dry season, the yield of both fresh and dry weight shows that P4 produced garlic that was not significantly different from the treatments with higher cultivation inputs.



**Figure 5:-** Harvest yield of each input package. Fresh weight (FW) and dry weight (DW) after drying for one month.

The water deficit happened when the garlic treatments had started bulb formation and required plentiful water. Water is very important to obtain maximum yield especially during bulb formation (Sadaria *et al.*, 1997). Bulbs tend to have reduced size if water stress occurs during bulb formation (Fabeiro Cortes *et al.*, 2003). In addition, Nam *et al.* (2007) stated that water stress influences both agronomic growth and bulb size.

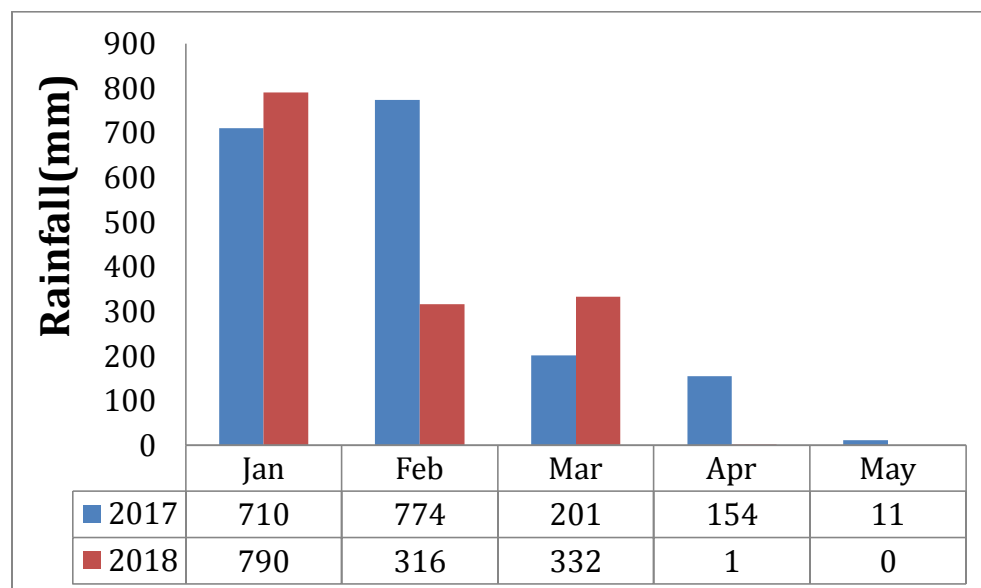
The environmental constraints which occurred during the field experiment in growing season of 2018 were very low rainfall during the cropping phase that requires lots of water for bulb formation and development. The lower rainfall and fewer rainy days that occurred from early April 2018 when crop growing conditions entered a generative phase that required plentiful water caused the suboptimal growth of the crops and development of bulbs was disrupted. When we compared garlic yield based on the farmers' existing practices (P1) with farmers' yield during a normal season, the garlic yield was reduced by almost 40-50% due to water stress.

### Environmental constraints

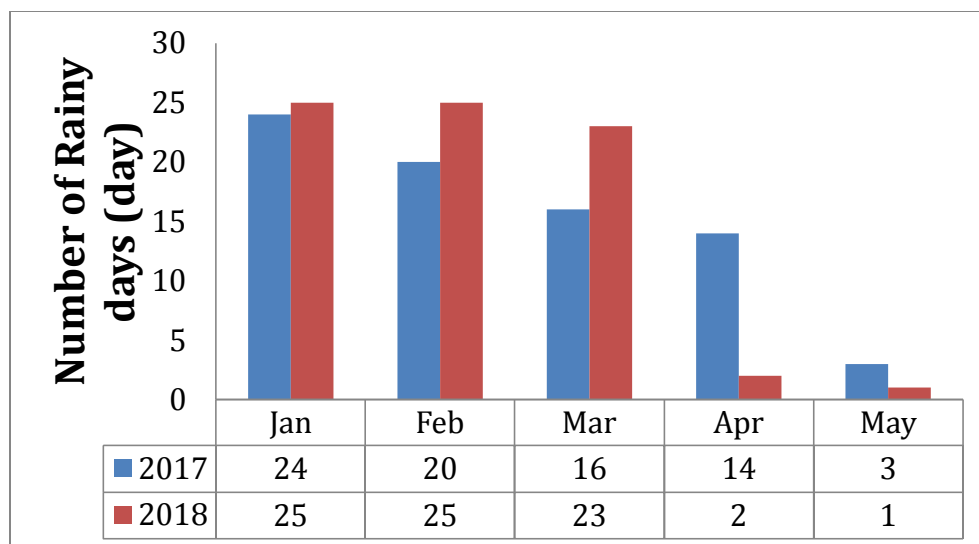
This 2018 field experiment was affected by a lack of rain from the beginning of April when the crops were 45 days old and beginning bulb formation. Treatments which were planted from the 17-18 February received sufficient rainfall during early vegetative growth, but from early April rainfall in the Sembalun highlands was far below average which meant the crops were water stressed during the period when they needed water most. Rainfall data for the Sembalun highlands during the growth of the field experiment can be seen in Figures 6 and 7.

Figure 6 shows the comparison of rainfall in 2017 and 2018. In April 2018 the rainfall deficit was 153 mm compared to April 2017 which had rainfall of 154 mm. Likewise; in May 2018 there was no rain at the experimental site, whilst 11 mm of rain fell in the same month of the previous year. The 2018 rainfall is an anomaly because in previous years from April and May there has been sufficient rain for crops in the rainfed areas in Sembalun highlands according cooperating farmers.

Figure 7 shows the comparison of rainy days in the Sembalun highland during the field experiment sown from 17-18 February 2018. The number of rainy days during the vegetative growth period, i.e from February to March 2018, shows enough rainy days (even relatively excessive). However, from the beginning of April the dry season occurred early, therefore the number of rainy days when the crops still needed water was very limited. In 2017 April and May had 14 and 3 rainy days respectively, while in 2018 April and May had only 2 and 1 rainy day respectively.



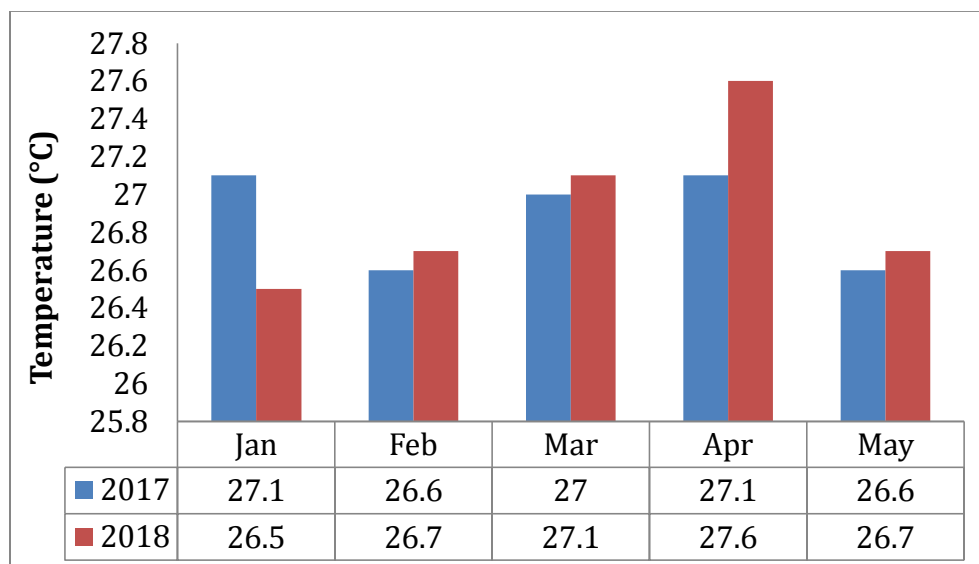
**Figure 6:-** Rainfall in the Sembalun highlands during the field experiment of input-saving garlic cultivation in growing season of 2018.



**Figure 7:** - Number of rainy days in the Sembalun highlands during the field experiment in the growing season of 2018.

In addition, there was an increase in temperature, especially in March and April 2018 compared to the same month in 2017. In April 2018, the maximum temperature was 27.6°C while in the same month of the previous year was only 27.1°C (Figure 8).

The maximum temperature in April 2018 reached 27.6°C while in the same month of the previous year it was held a degree lower at 27.1°C. We also felt this temperature increase when we were in the field due to the wind accompanied by heat waves which also affected the speed of the crops were dry out as an additional result after the absence of rainfall. However, there were no data that indicated the level of wind speed accompanied by heat waves due to the unavailability of tools in the field to measure the data. Anonymous (1998) stated that garlic crops adaptive in temperature between 15-20°C. If the temperature is below 15°C, the crop growth is disrupted and slow, while if the temperature is above 27°C bulb formation is also disrupted.



**Figure 8:** - Air temperature in the Sembalun highlands during the field experiment in growing season of 2018

### Conclusions:-

Conclusions from the input-saving garlic research on rainfed highlands of Eastern Lombok in the growing season of 2018 include:

The plant height of all garlic treatments at 4, 6 and 8 WAS did not show significant differences. Furthermore, leaf width also was not significantly difference between treatments. Treatment yield at harvest (fresh weight) was not significantly different for each cultivation input package. Likewise, dry weight of bulbs after sun drying for one month showed no significantly difference between treatments. Although these yields were suboptimal due to the early onset of the dry season, both fresh and dry weight of the lowest cultivation input package (P4) was not significantly different from the treatments with higher cultivation inputs.

### Acknowledgement:-

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