Sorghum cultivation of the ratoon system for increased yields in dry land

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Abstract. Planting sorghum twice a year on dry land is constrained by the short duration of rainfall, so it requires technology to increase yields with the ratoon cropping system. The research was carried out in Agricultural Technology Research and Assessment Installation of Bajeng, Gowa, South Sulawesi from March to October 2019. The superior genotypes of sorghum were planted on marginal land as the main crop with a spacing of 75 cm x 20 cm (66,666 plants/ha). The ratoon plant used a split-split plot design. The main plot consisted of two mulches: M1= no mulch + 50% dose of main crop fertilization and M2= sorghum stover mulch + biodecomposer 1kg/ha without NPK fertilizer. The sub-plots consisted of 2 populations: P1= population of 66,666 plants/ha (1 shoot/hole), P2=133,332 ratoon plants/ha (2 shoots per hole). The sub-sub-plots consisted of 5 (five) genotypes/varieties of sorghum: V1= Numbu, V2= No.58-1, V3= No. 86.1, V4= No.103-1 and V5=No. 113-1, so that 20 treatment combinations were obtained with 3 replications. The results showed that to obtain high grain yield in ratoon cultivation in dry land, NPK fertilization (150-100-50)/ha is still necessary. The increase in population density of ratoon from 66,666 to 133,333 plants/ha significantly affected the increase in grain yield. Sorghum genotype No. 58-1, No. 86-1, No. 103-1 and No. 113-1 is technically and economically feasible to be developed in the cultivation of the double harvest ratoon system with the profit (Rp 10,989,000-12,247,500/ha) from the cultivation of sorghum once the main crop (Rp 4,003,000-4,856,000). The R/C value is 2.00-2.10 and the MBCR value is 2.27-2.38.

1. Introduction
Sorghum is known as a drought tolerant plant, so its cultivation is directed to dry and marginal land with a relatively warmer agro-climate type. Some areas, such as East Java, sorghum is grown in dry climates, short rainy seasons and less fertile soils. Global climate change between regions and over time causes losses that must be borne by farmers [1]. Sorghum has several benefits, both as staple food and as a substitute for rice or flour. The nutritional content of sorghum grains is quite competitive with other foodstuffs such as rice and corn. To obtain sufficient food on marginal lands, sorghum is an alternative crop because it can adapt better to marginal lands than other cereals such as rice or corn. Sorghum can be grown in the ratoon system with lower yields than the main crop, but there are strains such as No. 15/226 can produce higher grains than the main crop [2]. Sorghum Hellepence gene pool is a source of many alleles that are useful for improving the character of sorghum ratoon [3].

Sorghum plants are very responsive to N fertilization depending on the level of soil fertility and the variety used. Likewise, P, K and S fertilizers are needed to maintain the balance of nutrients in the soil. Potassium is also needed to encourage the production of carbohydrates, besides that potassium is needed to help absorb water by the roots and prevent evaporation of water out of the leaves, thus potassium plays a role in reducing the sensitivity of sorghum plants to drought [4].
Fertilization of sorghum plants depends on soil fertility. Farmers in many places use Urea in the range of 45-224 kg N/ha in sorghum cultivation. N fertilization as much as 200 kg/ha gave the highest biomass 64.80 t/ha, 8% protein, and the lowest dissolved carbohydrates 12.80%, and fiber content 31.90% [5]. The optimal N and P requirements of sweet sorghum for the long term based on total production and fertilization rates ranged from 90-110 kg N/ha and 15-20 kg/ha P2O5 [6]. The increase in plant population and the dose of N can increase the yield of sorghum grains [7].

In Indonesia, sorghum does not have to be a staple food, but a supplement to rice. Rice with a mixture of 20-25% sorghum and 75-80% rice is not expected to change the texture and aroma, even in crisis conditions a mixture of 50% sorghum and 50% rice is still feasible and delicious to eat [8]. Sorghum starch of the Numbu variety is suitable for ingredients in dairy products, mayonnaise, sauces and salads [9].

Gluten-free sorghum grains have the potential to be used as an alternative to wheat flour. There are thousands of sorghums that have been characterized for grain, flour or final product quality such as the manufacture of good quality egg noodles in China [10]. It was further stated that grain size and weight are key factors in the differences in grain quality, flour and end use, and have been taken into account in the selection of hybrid sorghum. Birds can reduce grain yields by up to 73% [11]. Meanwhile, Anthracnose can reduce the yield of sorghum grains by up to 86% [12].

Marginal dry land generally has less number of rainy days, low rainfall and short duration, so sorghum ratoon technology is more appropriate to be developed in areas like this, because to plant with grains in this condition is constrained by drought. The buds of the main crop of sorghum can be used as mulch on the left and right sides of the row of ratoon+decomposer plants which serves to improve the microclimate of the plant by increasing soil moisture, adding nutrients and improving the soil microbial environment. In addition, the increase in the ratoon population by leaving more than one shoot per clump, so that the population can be increased compared to the main plant population. According to Mourtzinis et al. (2016), planting several varieties of sorghum using a ratoon system with fertilizer 33 kg N/ha and 50 kg P2O5/ha as a ratoon starter can increase profits in the range of $12.2 - $37.2/ha and the amount of grain yield is influenced by specific location, climate and species land where it is developed. This study aims to obtain an adaptive and efficient sorghum ratoon cultivation system for increasing yields in marginal dry land areas.

2. Materials and Methods

2.1 Main sorghum planting

This research was carried out on marginal dry land in Agricultural Technology Research and Assessment Installation of Bajeng, Gowa, South Sulawesi from March to October 2019. Research activities were carried out in two stages. The first stage was improving the cultivation of superior genotypes of sorghum on marginal land as the main crop where the genotypes were arranged according to a split-split plot design with 3 replications at a spacing of 75 cm X 20 cm (66,666 plants/ha). The ratoon plant used a split-split plot design. The main plot consisted of two mulches: M1= no mulch + 50% dose of main crop fertilization and M2= sorghum stover mulch + biodecomposer 1kg/ha without NPK fertilizer. The sub-plots consisted of 2 populations: P1= population of 66,666 plants/ha (1 shoot/hole), P2= 133,332 ratoon plants/ha (2 shoots per hole). The sub-sub-plots consisted of 5 (five) genotypes/varieties of sorghum: V1= Numbu, V2= No. 58-1, V3= No. 86.1, V4= No.103-1 and V5= No. 113-1, so that 20 treatment combinations were obtained with 3 replications. The treatment combinations were: 1. M1P1V1, 2. M1P1V2, 3. M1P1V3, 4. M1P1V4, 5. M1P1V5, 6. M1P2V1, 7. M1P2V2, 8. M1P2V3, 9. M1P2V4, 10. M1P2V5, 11. M2P1V1, 12. M2P1V2, 13. M2P1V3, 14. M2P1V4, 15. M2P1V5, 16 M2P2V1, 17. M2P2V2, 18. M2P2V3, 19. M2P2V4, 20. M2P2V5.

The experimental plot size was 5 m x 3 m with a spacing of 75 cm x 20 cm (66,666/ha, 1 plant per hole in the main plant). Fertilization for the main plant was 300 kg Urea/ha, 200 kg SP36/ha and 100 kg KCl/ha at 10 days after planting by applying 50% Urea and all SP36 and KCl as the first fertilization and the second fertilization 50% Urea remaining from the first fertilization is given at 30 days after planting (DAP) by applying beside the plant and given enough water when the leaves of the plant begin
to roll. Meanwhile, fertilization on ratoon plants without mulch was given 150 kg of Urea, 100 kg of SP36 and 50 kg of KCl, only one fertilization at the time of ratooning.

Parameter to be observed:
1. Analysis of soil samples before the study
2. Plant height at 30 DAP and at harvest at the main crop
3. Wet and dry weight of the main plant
4. Stem circumference/diameter, fresh leaves at the time of main crop harvest
5. 50 percent flowering age and crop harvest age
6. Grain yield and yield components (panicle length, panicle diameter, 1000 grain weight).

2.2 Ratoon sorghum cultivation
The second stage was Cultivation of superior sorghum genotype on marginal land with ratoon plant system. Food sorghum in the main crop was then properly maintained and the ratoon system begins when the panicle was physiologically ripe or at harvest. The ratoon planting system was carried out by cutting the stems of the main plant, leaving about 5-10 cm above the soil surface. Next enough watering to keep it moist so that new shoots appear immediately. Fertilization according to the treatment of 50% of the dose of the main crop fertilizer was given after cutting the stems of the main plant. Thinning of ratoon shoots was carried out at the age of 10-15 days after cutting the main plant stem by leaving 1 shoot for a population density of 666,666 plants/ha and 2 shoots for 1333,330 plants/ha).

Selected ratoon plants that were sturdy, uniform, did not overlap when choosing more than one shoot, emerge from below the soil surface, or shoots that grow on segments 1 and 2 and free from pests and diseases. The maintenance of ratoon plants was carried out optimally until harvest. Plant maintenance included: thinning, weeding, hoarding, irrigation, and controlling plant pests and diseases. Parameters to be observed as follows:
1. Percentage of growing ratoon plants
2. Plant height at 30 DAP and when harvesting ratoon plants,
3. The flowering age of 50% and the harvesting age of the ratoon plant
4. Wet and dry weight of ratoon plant stover,
5. Stem diameter, number of fresh leaves of ratoon before harvest,
6. Yield and yield components (panicle dry weight, panicle length, panicle diameter, 1000 grain weight).
7. Percentage of yield reduction for main crops and total yield of main crops and ratoons.

3. Result and Discussion
3.1 Main crop vegetative growth
The growth of the selected sorghum genotype for food was quite good, indicated by the appearance of plant height, number of green leaves at harvest, age of flowering, stem diameter and overall stover weight under normal conditions. The main plants showed differences in growth components caused by differences in the growth ability of the tested sorghum genotypes because the fertilizer dose and plant population were the same for all genotypes (Table 1). According to [13], stem diameter and flowering age 50% were directly positively correlated with the results of sorghum panicle weight.

| Treatments (NPK, Population, Genotype) | Plant Height (cm) | Number of green leaves (strands) | Flowering age 50% (days) |
|---------------------------------------|-------------------|----------------------------------|------------------------|
| NPK (300-200-100)                      | 217,4 ns          | 5,08                             | 53,2 ns                |
| NPK(300-200-100)                       | 215,8             | 4,40                             | 53,3                   |
| 66.666 plant ha †                      | 218,6 ns          | 5,10 ns                          | 53,3 ns                |
| 66.666 plant ha †                      | 214,7             | 5,04                             | 52,9                   |
| Numbu                                 | 230,9 a           | 5,44 a                           | 52,8 bc                |
3.2 Main crop generative growth

In the generative development phase, the plant was quite good, indicated by the appearance of the yield and its components which included dry panicle weight, panicle length, panicle diameter, grain weight and 1000 grain weight. The difference in the results achieved seems to be influenced by differences in the genotype/variety used as evidenced by significant differences in panicle length, panicle diameter, grain yield and 1000 grain weight. Genotype No. 58-1 yielded the highest dry grain (10% water content) of 6.45 t ha\(^{-1}\), which was significantly different from the Numbu variety and other genotypes (Table 2).

The sorghum genotype greatly influences the flowering age and weight of 1000 grains and there is an interaction between the genotype and the cropping system which is indicated by the flowering age and weight of 1000 grains [14]. Sorghum can also be used as the main crop as forage and ratoon for grain production [15]. According to [7] that the yield of sorghum grains can be increased by increasing the population density of 8-20 plants/m\(^2\) with an increase in nitrogen dose (40-120 kgN ha\(^{-1}\)).

3.3 The vegetative growth of the ratoon plant

The use of NPK fertilizer, sorghum stover mulch from the main crop and the increase in plant population density did not significantly affect the components of plant height, number of green leaves, stem diameter, stover weight and dry weight of the stover. While the use of sorghum genotype/variety significantly affected the components of plant height, stem diameter, stover weight and dry weight of plant stover (Table 3). The growth of the main plant has a direct effect on the height of the ratoon plant and the vegetative ratoon has a direct effect on the production of the ratoon plant [16]. According to Ferdian et al. [17] that sorghum plant breeding can target simultaneously for the production of biomass and grains. Farmers in Africa 58% store sorghum waste in the form of hay for the provision of animal feed [11].

### Table 2. Appearance of sorghum genotype results as the main crop in the ratoon cropping system.

Gowa, South Sulawesi, 2019

| Treatments (NPK, Population, Genotype) | Panicle weight (g) | Panicle length (cm) | Panicle diameter (cm) | Grain yield (t ha\(^{-1}\)) | Weight 1000 grains (g) |
|----------------------------------------|-------------------|---------------------|-----------------------|--------------------------|-----------------------|
| NPK(3000-200-100)                      | 130,9 ns          | 23,54 ns            | 7,38 ns               | 6,10 ns                  | 37,91 ns              |
| NPK(3000-200-100)                      | 127,8             | 23,36               | 7,27                  | 6,12                     | 37,13                 |
| 66.666 plant ha\(^{-1}\)              | 129,6 ns          | 23,46 ns            | 7,23 ns               | 6,21 ns                  | 38,10 ns              |
| 66.666 plant ha\(^{-1}\)              | 129,1             | 23,45               | 7,33                  | 5,99                     | 37,07                 |
| Numbu                                 | 125,9 ns          | 21,30 a             | 7,33 a                | 5,98 b                   | 41,30 a               |
| No. 58-1                              | 134,3             | 21,40 a             | 7,44 a                | 6,45 a                   | 41,33 a               |
| No. 86-1                              | 131,1             | 22,17 a             | 7,43 a                | 6,12 b                   | 38,17 a               |
| No. 103-1                             | 129,0             | 31,27 b             | 6,92 b                | 6,01 b                   | 25,92 b               |
| No. 113-1                             | 126,5             | 21,16 a             | 7,22 ab               | 6,04 b                   | 41,10 a               |
| CC (a)                                | 25,1              | 7,5                 | 8.2                   | 31,6                     | 7,4                   |
| CC (b)                                | 7,4               | 3,0                 | 3,5                   | 12,6                     | 10,0                  |
| CC (c)                                | 9,6               | 9,3                 | 6,0                   | 12,0                     | 11,6                  |

Numbers in the same column followed by the same letter are not significantly different according to the 0.05 DMRT test.
Table 3. Agronomic performance of sorghum genotype ratoon plants in the ratoon cropping system.
Gowa, South Sulawesi, 2019

| Treatments (NPK, Population, Genotype) | Plant height (cm) | Number of green leaves (strands) | Stover Diameter (cm) | Fresh weight of stover (t ha⁻¹) | Safe dry weight (t ha⁻¹) |
|--------------------------------------|-------------------|---------------------------------|----------------------|-------------------------------|-------------------------|
| Without stover mulch+ NPK (150-100-50) | 174,1 ns          | 3,78 ns                         | 1,83 ns              | 18,67 ns                      | 3,47 ns                 |
| Without NPK+Stover mulch + Decomposer 1 kg ha⁻¹ | 174,4 ns         | 3,98                             | 1,74                 | 18,07                         | 3,95                    |
| 66.666 plant ha⁻¹ | 173,2 ns         | 3,97 ns                         | 1,80 ns              | 18,12 ns                      | 3,25 ns                 |
| 133.330 plant ha⁻¹ | 172,8 ns         | 3,80                             | 1,78                 | 18,72                         | 3,20                    |
| Numbu | 182,3 a          | 3,99 ns                         | 1,83 a               | 22,04 a                       | 3,56 a                  |
| No. 58-1 | 185,7 a         | 3,90                             | 1,74 b               | 19,12 a                       | 3,30 a                  |
| No. 86-1 | 178,9 a         | 3,86                             | 1,71 b               | 19,30 a                       | 3,04 ab                 |
| No. 103-1 | 144,2 b         | 3,96                             | 1,81 a               | 12,97 b                       | 2,24 b                  |
| No. 113-1 | 180,3 a         | 3,70                             | 1,80 a               | 18,62 a                       | 3,43 a                  |
| CC (a) | 10,1             | 9,3                              | 2,0                  | 25,0                          | 33,2                    |
| CC (b) | 8,9              | 18,2                            | 11,7                 | 32,0                          | 21,4                    |
| CC (c) | 11,3             | 21,2                            | 12,2                 | 29,3                          | 16,5                    |

Numbers in the same column followed by the same letter are not significantly different according to the 0.05 DMRT test.

3.4 Generative growth of ratoon plants
The application of chemical fertilizers in the form of Urea, SP36, KCl (150-100-50) or without fertilizer but given mulch+ biodecomposer on the sorghum ratoon genotype showed a significantly different effect on dry panicle weight, panicle length, panicle diameter and grain yield, but had no effect significantly to the weight of 1000 grains. This means that the cultivation of sorghum with a ratoon planting system on marginal lands still requires chemical fertilizers to obtain higher grain yields. Plant population density had a significant effect on increasing grain yield although not significantly on panicle dry weight, panicle length, panicle diameter and 1000 grain weight. An increase in population decreases the production of individual plants but increases the yield per unit area of land [18].

The use of sorghum genotype/variety showed a significant effect on panicle length and 1000 grain weight, but had no effect on grain yield, dry panicle weight and panicle diameter. When viewed from the use of the tested genotype/variety as a ratoon plant, it shows that the genotype No. 58-1 yielded the highest dry grain (10% water content) (5.25 t/ha) which was not significantly different from Numbu or other genotypes (Table 4). This means that genotype No. 58-1, No. 86-1, No. 103 and No. 113-1 is feasible to be proposed as a candidate variety for sorghum cultivation with ratoon cropping system in marginal dry land. Planting sorghum Phule Vashdha variety increased grain yield higher 65% than local variety [16].

Table 4. Appearance of sorghum genotype ratoon crop yields in the ratoon cropping system. Gowa, South Sulawesi, 2019

| Treatments (NPK, Population, Genotype) | Panicle dry weight (g) | Panicle length (cm) | Panicle diameter (cm) | Grain yield (t/ha) | Weight 1000 grains (g) |
|--------------------------------------|------------------------|---------------------|-----------------------|-------------------|------------------------|
| Without stover mulch + NPK (150-100-50) | 70,04 a               | 21,31 a            | 6,79 a                | 5,32 a            | 35,51 ns               |
| Without NPK+Stover mulch + Decomposer 1 kg ha⁻¹ | 66,10 b              | 20,14 b            | 6,51 b                | 4,93 b            | 35,87                  |
| 66.666 tan/ha | 69,36 tn             | 21,27 tn           | 6,67 tn               | 4,65 b            | 35,86 tn               |
| 133.330 plant ha⁻¹ | 66,10 b             | 20,14 b            | 6,51 b                | 4,93 b            | 35,87                  |
| Numbu | 66,10 b             | 20,14 b            | 6,51 b                | 4,93 b            | 35,87                  |
| No. 58-1 | 66,10 b             | 20,14 b            | 6,51 b                | 4,93 b            | 35,87                  |
| No. 86-1 | 66,10 b             | 20,14 b            | 6,51 b                | 4,93 b            | 35,87                  |
| No. 103-1 | 66,10 b             | 20,14 b            | 6,51 b                | 4,93 b            | 35,87                  |
| No. 113-1 | 66,10 b             | 20,14 b            | 6,51 b                | 4,93 b            | 35,87                  |
| CC (a) | 66,10 b             | 20,14 b            | 6,51 b                | 4,93 b            | 35,87                  |
| CC (b) | 66,10 b             | 20,14 b            | 6,51 b                | 4,93 b            | 35,87                  |
| CC (c) | 66,10 b             | 20,14 b            | 6,51 b                | 4,93 b            | 35,87                  |
3.5 Total yield of main crops and ratoon

Ratoon sorghum plants that were given NPK fertilizer (150-100-50) kg/ha showed a lower yield reduction on the main crop (12.76%) than without NPK fertilizer, but were given mulch + biodecomposer (19.42%). The total yield of main crops and ratoons fertilized with NPK was also higher than without NPK fertilizer given mulch + Bioser decomposer. Furthermore, the increase in population density from 66,667 plants to 133,333 can increase the yield from 6.62% to 25.09%. Meanwhile, the lowest yield reduction for main crops was shown by genotype No.103-1 at 13.15%. Meanwhile, the total grain yield of the main plant plus the highest ratoon was obtained at genotype No. 58-1 of 11.69 t/ha twice harvested (Table 5). The sorghum genotype ratoon plants produced 9.14% higher grains than planting from grains under water stress conditions [18]. Reducing the number of tillers in ratoon I to 3 tillers gave the highest yield compared to 1, 2 and 4 tillers [19]. According to Rao [20] that planting Phule Vashdha sorghum variety 65% increase grain yield compared to local variety.

Table 5. Total dry grain yield of sorghum genotype with ratoon cultivation system. Gowa, South Sulawesi, 2019

| Treatments ( NPK, Population, Genotype) | Main crop yield (t ha⁻¹) | Yield of ratoon grains (t ha⁻¹) | Yield drop (%) | Total yield (t ha⁻¹) |
|-----------------------------------------|--------------------------|-------------------------------|----------------|-------------------|
| Without stover mulch + NPK (150-100-50) | 6,10                     | 5,32                          | 12,76          | 11,42             |
| Without NPK+Stover mulch+ Decomposer 1 kg ha⁻¹ | 6,12                     | 4,93                          | 19,42          | 11,05             |
| 66,666 plant ha⁻¹                          | 6,21                     | 4,65                          | 25,09          | 10,87             |
| 133,330 plant ha⁻¹                         | 5,99                     | 5,60                          | 6,62           | 10,91             |
| Numbu                                    | 5,98                     | 4,90                          | 20,41          | 10,88             |
| No. 58-1                                 | 6,45                     | 5,25                          | 18,60          | 11,69             |
| No. 86-1                                 | 6,12                     | 5,16                          | 15,74          | 11,28             |
| No. 103-1                                | 6,01                     | 5,22                          | 13,15          | 11,23             |
| No. 113-1                                | 6,04                     | 5,08                          | 15,89          | 11,12             |

4. Conclusion

1. To obtain sorghum grain yields in adequate ratoon cultivation in dry land, NPK fertilization (150-100-50) kg ha⁻¹ is still needed.
2. The increase in population density of ratoon from 66,666 plants/ha to 133,333 plants ha⁻¹ had a significant effect on increasing the yield of sorghum grains.
3. Sorghum genotype No. 58-1, No. 86-1, No. 103-1 and No. 113-1 is technically feasible to develop by cultivating the ratoon cropping system on dry land.
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