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The Early Growth in Sorghum Plant under Combined Treatments of Soil Moisture and Ammonium Sulfate Application

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Introduction

"How do fertilizer application and soil moisture affect the crop growth or crop yield, respectively?" While this question has been discussed on a great many reports[3,5,7,9], it has become clear that the quantitative relationships between fertilizer application and soil moisture, and crop growth or crop yield vary considerably with the years, and are dependent on biological factors, such as the kind of crop, variety and growing behavior, climatic factors, such as air temperature, humidity and solar radiation, as well as edaphic factors, such as soil texture, depth of cultivated soil and fertility[3]. Thus, it is naturally expected that if the amount of fertilizer application and soil moisture condition vary, the quantitative relations between soil moisture content and the amount of fertilizer application, and crop growth and crop yield may also vary, respectively.

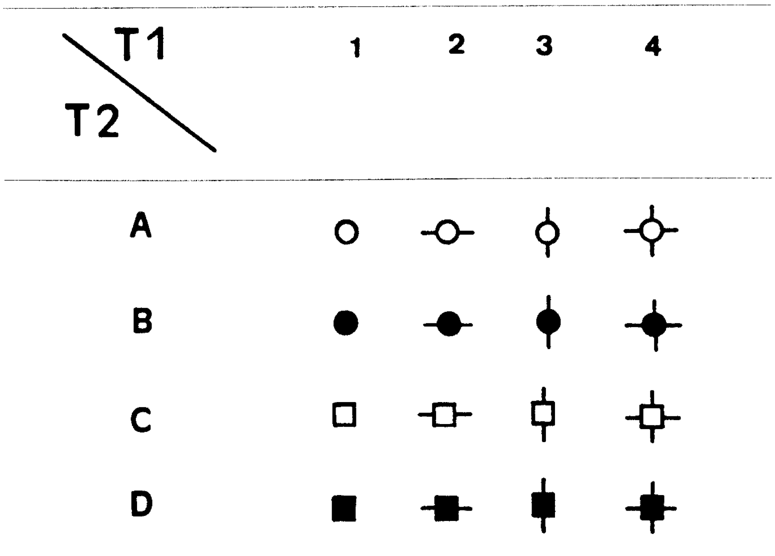
However, "How do the combined conditions of fertilizer application and soil moisture affect crop growth or crop yield?" This question has been discussed in only a few reports. In the present paper, the relationships between the soil moisture ratio and the amount of ammonium sulfate application, and the early growth increment in sorghum plant were researched. The effects of soil moisture and ammonium sulfate application upon water relations such as evapotranspiration, transpiration and water use efficiency were also discussed.

Materials and Methods

The experiment was carried out inside the vinyl plastic hothouse in the Experimental Farm of the Faculty of Agriculture, at Kagoshima University from 15 April to 6 June, 1985. One hundred grains of the sorghum cv. snow brand were sown in 13 litter seedling culture boxes filled with a uniform soil of 4.78 kg of dried soil that was passed through a sieve of 5 mm across, on 15 April.

At the beginning of the treatments (22 April), the soil moilture ratio in each seedling culture box was kept in about 35%. Sixteen treatments were imposed on the plants. The treatments used are shown in Table 1. The entire amount of ammonium sulfate, superphosphate of lime and potassium chloride were applied as basal dressing on 22 April. Although superphosphate of lime and potassium chloride were applied at 1.66 g/pot of P_2O_5 and K_2O basis in all the treatments, the amount of ammonium sulfate application was parceled out into four steps, that is, 0 g, 3.96 g, 7.91 g and 15.84 g/pot of ammonium sulfate, in accordance with those treatments. The soil moisture treatments were also parceled out into four steps, that is, 20%, 27%, 35% and 42%. Soil moisture control was carried out by a gravimetric method, and the amount of water supplied

Table 1. Kind of treatment and its symbol



Note: T1 shows the amount of ammonium sulfate applied in this study. The amount of ammonium sulfate application was 0, 3.96, 7.91 and 15.84 g/pot in 1-, 2-, 3-, and 4- division, respectively.
T2 shows soil moisture treatment. The mean soil moisture ratio during the experiment was 13.9～16.9, 18.2～21.0, 22.2～26.0 and 26.9～30.0% in A-, B-, C- and D-division, respectively.

in order to keep the soil moisture condition constant was sprinkled on the soil surface every day. However, because the soil moisture conditions changed gradually with the increases in evapotranspiration and plant weight, the soil moisture ratio used in this paper was the average value during the treatments.

On 6 June, 45 days after the beginning of the treatments, one hundred plants with no replications were harvested from each division. These plants were separated into leaf blades, leaf sheaths, culms and roots, and were dried at 80°C for 72 hours to get dry weight.

Results

1. Relationships between growth increment, the soil moisture ratio, and the amount of ammonium sulfate application

Table 2 shows how the early growth increment in sorghum plants changed with the soil moisture ratio and the amount of ammonium sulfate application. The average growth increment within each soil moisture-division increased with an increasing in the soil moisture ratio. The average growth increment within each ammonium sulfate application-division reached maximum value at 3.96 g/pot-division, and decreased when the amount of ammonium sulfate application became either greater or less, than 3.96 g/pot.

On the other hand, the coefficient of variation within each treatment-division tended to increase gradually with a decrease in the soil moisture ratio and an increase in the amount of ammonium sulfate application, respectively (Table 2).

Fig. 1 shows the relationship between the soil moisture ratio and growth increment.

Table 2. Effects of the ammonium sulfate application and soil moisture condition upon growth increment in sorghum plants (g/pot).

T2 \ T1	1	2	3	4	X	C. V.
A	48.8	29.6	26.1	11.4	29.0	53.0
B	83.0	80.4	70.0	43.7	69.3	25.9
C	103.1	140.6	107.4	74.7	106.4	25.4
D	103.7	162.1	145.1	115.0	131.5	20.5
X	84.6	103.2	87.2	61.2	84.0	17.3
C. V.	30.4	58.2	58.5	72.2	53.2	

Note: T1 and T2 are the same as those shown in Table 1.
X indicates average value (g/pot).
C. V. indicates coefficient of variation (%).

Although the growth increment tended to increase with an increase in the soil moisture ratio in all the ammonium sulfate application-divisions, the promotive effect of soil moisture increase upon growth increment varied considerably with the amount of ammonium sulfate application. In addition, the lowest limit value of available soil moisture—the soil moisture ratio observable when growth increment becomes zero—also tended to vary with the amount of ammonium sulfate application.

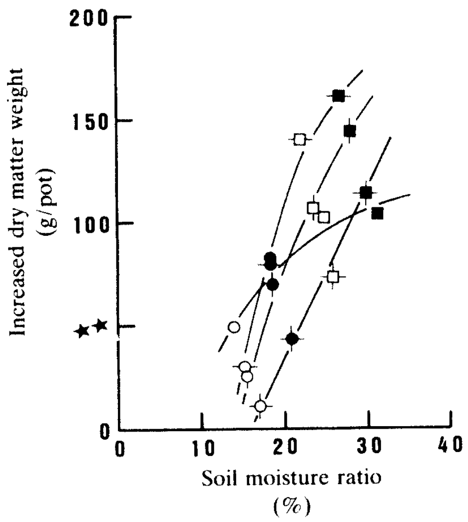


Fig. 1. Relationship between the soil moisture ratio and increased dry matter weight. Symbols are the same as those shown in Table 1.

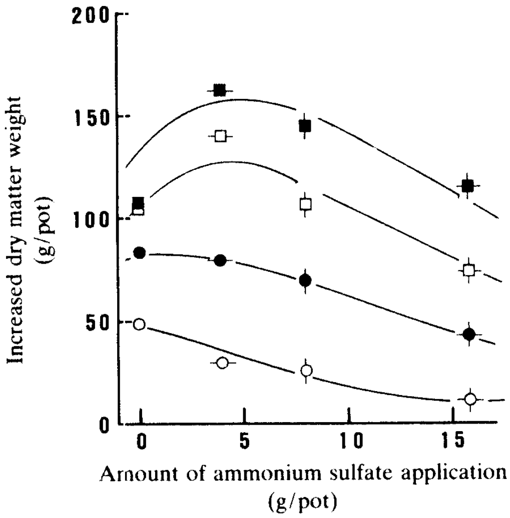


Fig. 2. Relationship between the amount of ammonium sulfate application and increased dry matter weight. Symbols are the same as those shown in Table 1.

Fig. 2 shows the relationship between ammonium sulfate application and growth increment. The results showed that growth increment increased with an increase in the soil moisture ratio, it also showed that there was an optimum curvilinear relation between growth increment and the amount of ammonium sulfate application in all the soil moisture-divisions, and that the optimum amount of ammonium sulfate application tended to increase gradually with an increase in the soil moisture ratio.

2. Influences of soil moisture and ammonium sulfate application upon the relationship between growth increment and evapotranspiration

Fig. 3 shows the relationship between growth increment and evapotranspiration. Evapotranspiration increased in proportion to the growth increment in all soil moisture-divisions, though the intercept varied with the soil moisture condition.

On the assumption that the evapotranspiration, when growth increment becomes zero, could be regarded as "unavailable evapotranspiration" or evaporation, the relationship between the soil moisture ratio and "unavailable evapotranspiration" (≒evaporation) is shown in Fig. 4. The

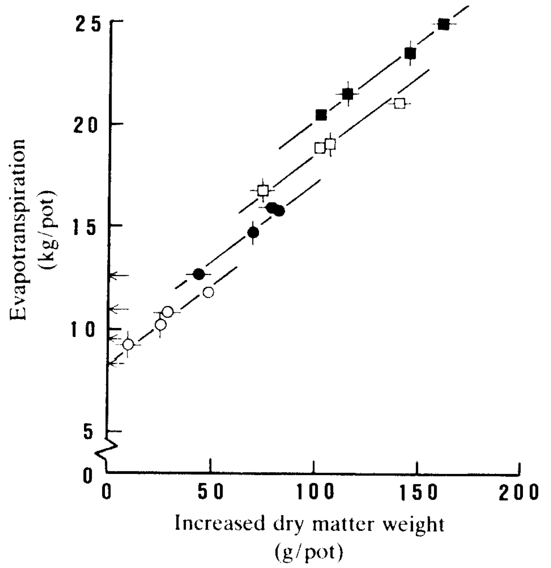


Fig. 3. Relationship between increased dry matter weight and evapotranspiration.
Symbols are the same as those shown in Table 1.
Arrow indicates "unavailable evapotranspiration" in each soil moisture-division.

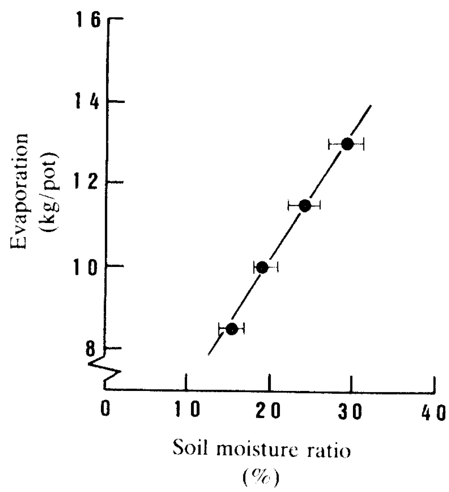


Fig. 4. Relationship between the soil moisture ratio and evaporation*[1].
*[1]: "Unavailable evapotranspiration" was regarded as nearly equal evaporation.

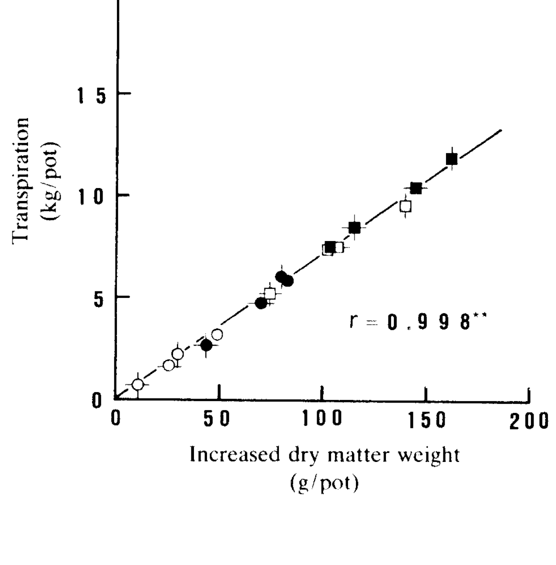


Fig. 5. Relationship between increased dry matter weight and transpiration*[2].
Symbols are the same as those shown in Table 1.
**: Significant at 1% level.
*[2]: Transpiration was estimated by deducting unavailable evapotranspiration from evapotranspiration.

evaporation estimated in this way increased directly with an increase in the soil moisture ratio.

Fig. 5 shows the relationship between growth increment and transpiration which was assessed by deducting "unavailable evapotranspiration" from evapotranspiration. As a result, the influences of soil moisture and ammonium sulfate application upon the relationship between growth increment and transpiration could not be recognized at all. That is, the water use efficiency (increased dry matter weight/total transpiration) was kept at about 14 mg/g, independently of soil moisture condition and the amount of ammonium sulfate application.

Discussion

The growth increment in young sorghum plants increased with an increase in the soil moisture ratio in all the ammonium sulfate application-divisions. But, the promotive effect of soil moisture increase upon growth increment decreased gradually with an increase in the soil moisture ratio. This tendency became more conspicuous in the smaller ammonium sulfate application-divisions (Fig. 1). Also, "the lowest limit value of available soil moisture" or "the uppermost limit value of unavailable soil moisture" tended to increase gradually with an increase in the amount of ammonium sulfate application. In order to examine the relationship between those in detail, the soil moisture ratio when growth increment becomes zero was assessed by Balmukand's method[2]. The result is shown in Fig. 6. As a result, it was confirmed that the lowest limit value of available soil moisture increases in proportion as the amount of ammonium sulfate application increases. Therefore, it may be assumed that the linear increasing in the lowest limit value of available soil moisture occurring with the increase in the amount of ammonium sulfate application was caused by the rise in osmotic potential occassioned by the increase in solute. On the other hand, the relationship between the amount of ammonium sulfate application and growth increment was found to be a curvilinear relationship in all the soil moisture-divisions, although the optimum value observable when growth increment became maximum, varied with the soil moisture condition, from 0 g/pot in arid condition to 3.96 g/pot in moist condition. These results suggest that the soil moisture ratio and the amount of ammonium sulfate application acted as linear factor[8] and optimum factor[5] on the growth in young sorghum plants, respectively.

On the basis of this information, the effect of the soil moisture ratio and the amount of ammonium sulfate application upon early growth increment in sorghum plants were formulated by the following equation:

$$\left.\begin{aligned} 1/w &= 0.019511/(f-f_0)+0.0050931\cdot g/(f-f_0) \\ &\quad +0.0281537/(g+3.83)+0.00064677 \\ f_0 &= 0.2202186\ (g+3.83)+11.36 \end{aligned}\right\}\ \text{Eq. (1)}$$

where f, f_0, g and w are soil moisture ratio (%), the lowest limit value of available soil moisture (%), the amount of ammonium sulfate application (g/pot) and growth increment fixed on dry matter weight basis (g/pot), respectively. Fig. 7 shows the correlation between the calculated values and the observed values. The calculated values and observed values corresponded considerably well. Therefore, Eq. (1) will be considered to be an effective formula in estimating the effects of the soil moisture ratio and the amount of ammonium sulfate application upon the growth in sorghum plants at early stages. It is noteworthy in Eq. (1) that not only the independent effect of soil moisture (1st term) and ammonium sulfate application (3rd term) but also the interactive effect[3,5] of both factors (2nd term) were perceived. In addition, the

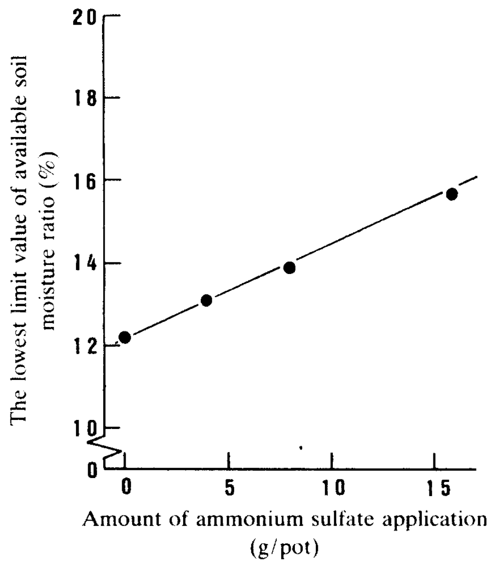


Fig. 6. Relationship between the amount of ammonium sulfate application and the lowest limit value of available soil moisture assessed by Balmukand's method.

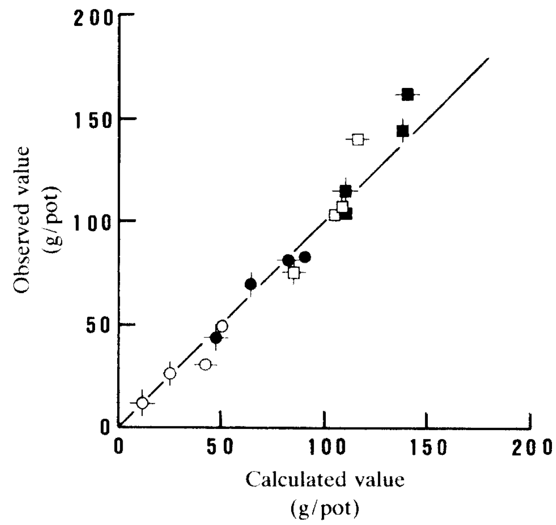


Fig. 7. Comparison of the culculated value of increased dry matter weight [based upon Eq.(1)] with the observed value. Symbols are the same as those shown in Table 1.

interactive effect was also perceived by the fact that the lowest limit value of available soil moisture rose with an increase in the amount of ammonium sulfate application. On the other hand, 2nd term in Eq. (1) suggests that the influencing power of soil moisture will increase relatively with an increase in the amount of ammonium sulfate application, and that the influencing power of the amount of ammonium application will increase relatively with a decrease in the soil moisture ratio. These suggestions are in accord with the results telling us that the coefficient of variation within each treatment-division increased gradually with a decrease in the soil moisture ratio and with an increase in the amount of ammonium sulfate application, respectively (Table 2).

In the rain-fed agriculture, if too little precipitation should occurs, the results of the past indicated that response to fertilizer would be nil, and that it may even be negative, if excessive vegetative growth is promoted by fertilizer, so that water reserves are depleted at an early stage and too little moisture remains in the soil at the time of grain formulation[1]. However, the results of this experiment suggest that ammonium sulfate application under low soil moisture conditions will make it possible to inhibit more directly sorghum growth at an early stage. If that be the case, by what sort of mechanism did the combined treatments of soil moisture and ammonium sulfate application affect sorghum growth?

The quantitative relationship between growth increment and transpiration, or water use efficiency, was constant, independently of the soil moisture ratio and the ammonium sulfate application (Fig. 5), although the quantitative relationship between growth increment and evapotranspiration varied with soil moisture condition (Fig. 3). That is, evaporation increased directly with an increase in the soil moisture ratio (Fig. 4). Such a linear relationship between the soil moisture ratio and evaporation has often been observed in the decreasing rate process[10]. Taking these results into consideration, it is assumed that both the soil moisture ratio and the amount of ammonium sulfate application may affect the growth increment through transpiration- and/or the sorption-process.

Summary

The sorghum cv. snow brand was made to be grown in 13 litter seedling culture boxes, under sixteen treatments, to which soil moisture-treatments of four steps and ammonium sulfate application-treatments of four steps were applied. The combined influences of soil moisture and ammonium sulfate application upon growth increment and water relations at early stages were observed.

The main results obtained were summarized as follows:

1. The coefficient of variation within each treatment-division increased gradually with a decrease in the soil moisture ratio and an increase in the amount of ammonium sulfate application, respectively (Table 2).

2. It was observed as a general trend that the growth increment increased with an increase in the soil moisture ratio, within the limits of soil moisture in this experiment, and that there was the optimum curvilinear relation between the growth increment and the amount of ammonium sulfate application (Table 2). However, the aspects of those responses changed remarkably with the amount of ammonium sulfate application and soil moisture condition, respectively. That is, the increase in the amount of ammonium sulfate application and in the soil moisture ratio tended to cause the increases in the lowest limit value of available soil moisture and in the optimum amount of ammonium sulfate application, respectively (Fig. 1, Fig. 2 and Fig. 6).

3. From the above-mentioned results, it was assumed that the influences of the combined treatments of soil moisture and ammonium sulfate application upon the growth of young sorghum plants were noted to be consisting of the interactive effects of soil moisture and ammonium sulfate application as well as the independent effects of those two factors (See Eq. 1).

4. On the other hand, the water use efficiency (increased dry matter weight/total transpiration) was fixed constant, independent of the soil moisture condition and the amount of ammonium sulfate application (Fig. 5). The result suggests that the influence of both factors upon the water use efficiency was considerably small, and that both factors caused the difference in growth increment through their influences upon transpiration- and/or the sorption- process.

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