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AGRICULTURAL RESEARCH CORPORATION
WESTERN SUDAN AGRICULTURAL RESEARCH PROJECT

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THE GOVERNMENT OF SUDAN
UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT
THE WORLD BANK
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WASHINGTON STATE UNIVERSITY

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## SUMMARY

Rapid drying of surface zone in the "goz" sands in North Kordofan (Sudan) is believed to be an important cause of poor emergence and failure of emerged crop seedlings. The resultant sparse coverage of the ground surface means an inefficient utilization of subsoil moisture supply and poor crop yields. There are circumstantial indications that available subsoil moisture supply is sufficient to support better crop yields. Management practices that minimize evaporative loss of water from the soil surface should be helpful in increasing water use efficiency and improving seedling growth and stand establishment.

An experiment was conducted to observe the effects of gum arabic on evaporative loss of water and sorghum seedling growth in potted goz sands. Powdered gum arabic was applied at the rate of 0, 5, 10, 15, and 20 g per pot. Results showed decreasing evaporation from the soil surface with increasing amounts of gum arabic. At the end of two days of drying the ratios of cumulative evaporation from the treated soil to that from the untreated soil were 0.81, 0.66, 0.53, and 0.50 for the 5, 10, 15, and 20 g treatments. These ratios

increased with time and would approach unity given an infinitely long drying time, as the total water in each pot was initially equal. Evaporation retarding effect of the gum arabic appeared to increase with time after application. However, there was an indication that effectiveness of the gum might begin to decrease after a prolonged aging.

Sorghum dry matter production increased with time for all treatments, but remained perceptibly lower for the untreated soil. After about a month of growth the amount of dry matter produced was 0.32, 0.42, 0.60, 0.82, and 0.87 g per pot for the 0, 5, 10, 15, and 20 g treatments, respectively.

Observations also indicated that only small concentrations of the gum were beneficial to plant growth. Amounts in excess of 20 g per pot, though very effective in retarding evaporation, produced crusts of high mechanical impedance which adversely affected water infiltration, emergence, and stem expansion.

Limitations to crop production due to poor water availability are severe in North Kordofan. Even expensive methods to improve the moisture supply would seem justified. A variety of hydrophillic polymers have been developed in industrialized countries and are now being used for increasing water retention in sandy soils and rehabilitation of arid lands. However, costs and importation problems restrict their use in Western Sudan. Gum arabic, on the other hand, is a local product of Sudan. Currently, almost all of the gum arabic

produced in Sudan is exported. Prices paid to the farmers are much lower than the export price the government charges. Local uses of gum arabic must affect the market and result in an increased incentive to produce more. An increase in plantations of gum producing acacia species would mean a progress towards environmental conservation (9).

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Water availability is the most important limiting factor in agricultural production in the North Kordofan Region of Western Sudan. It is a result of the combined effects of weather and soil conditions. The average annual rainfall is about 350 mm (1) and free water evaporation is estimated around 2400 mm per year (2). Almost all of the rain is received during the months from June to September. An uncertain beginning, a few relatively heavy showers, and several rainless periods of varying durations are characteristic features of the rainy season in North Kordofan. Most of the region is under sandy soils locally known as "goz" sands (3). These sands are deep and allow a rapid intake of rainwater. However, their water and nutrient holding capacities are very low. Organic matter content is negligible and there is no visible aggregation. As a result, the soil surface is highly susceptible to wind erosion.

One of the hydrologic features of goz sands is rapid drying of the surface zone following a rain. It results from the joint effects of the high atmospheric evaporativity and poor water holding capacity of the soil. While a dry surface zone acts as a barrier to the upward movement of water from the soil below, it offers an unfavorable environment for seed germination and seedling establish-

ment. Consequently, poor crop stand is a common sight in North Kordofan. Rapid infiltration of water into goz sands suggests that there may be moisture in the subsoil and below, which, if fully tapped could support additional crop growth. The seedling root zone dries rapidly during the intervals between rains. Plants with shallow root systems cannot utilize the water at depth and wither a few days after the rains cease. The resulting poor crop stand encourages the growth of weeds that deplete much of the subsoil moisture supply.

Thus, conservation of surface zone soil moisture stands out as a management problem of considerable significance to crop stand establishment and to increasing the efficiency with which the rainfall is utilized. Studies at the Central Arid Zone Research Institute in India (4) show that,with millet husk as a mulching material, the consumptive use for millet is about 270 mm of water and yields over 1700 kg/ha can be obtained. The 350 mm of rain that falls in El Obeid should be sufficient to produce a millet crop with a reasonable yield. Current millet yields in North Kordofan are under 500 kg/ha. Thus, there appears to be a potential for increasing yields through water conservation.

Management practices must aim at maximizing soil water storage and reducing losses from soil evaporation and weed transpiration. Beneficial effects of mulching in conserving soil moisture have been well documented (5). Planting in seed cradles and furrows have been shown to increase water-use efficiency. Soil amendments such as

farmyard manure, clay soil, gypsum, and organic soil conditioners (6) improve soil structure and water retention in light textured soils. In more recent times, hydrophillic polymers (e. g. Agrosoke, Terra-Sorb, Super Slurper) have been used to increase water retention in sandy soils (7,8). Western Sudan Agricultural Research Project has identified several soil and water conservation practices for field testing in North Kordofan. A serach for locally available soil amendments led us to try gum arabic as a potential evaporation retardant and a soil binding substance. This paper reports the results of initial testing.

## MATERIALS AND METHODS

The effect of gum arabic was tested on evaporative loss of soil water and sorghum seedling growth in goz sands. The goz sand was brought in from the top 15 cm in fields at the Western Sudan Agricultural Research Project Farm, El Obeid. The sand was air dried and filled in plastic containers (top I. D. 18 cm, bottom I. D. 15 cm and 15 cm height). The containers were provided with three holes in the bottom to allow drainage of water. A patch of gunnysack was placed over the holes so as to prevent flow of sand out through the holes. The air dry water content of the sand was found to be 0.004 g/g. On this basis each pot was filled with 4.016 kg air dry sand so as to give an exact amount of 4.0 kg sand on an oven dry basis. A toploading Mettler balance (weighing capacity 5 kg and an accuracy of $\pm$ 0.05 g) was used for weighing. The soil volume was esti-

mated by filling water in empty pots to the level of the soil surface and was found to be 2478 $cm^3$. This resulted in a dry bulk density of 1.614 $g/cm^3$ and an estimated pore volume of 969 $cm^3$.

After the pots were filled further treatment depended on whether plant growth was to be monitored or evaporative loss of water was to be monitored. In the case of evaporation experiments powdered gum arabic was added to the pots in varying amounts and mixed to about 3 cm depth. Then, an amount of 716 g tap water was applied to each pot in three installments over a period of 30 hours. All pots remained covered with lids until exposed to evaporation. In the case of plant growth experiments, pots were fertilized with 0.5 g urea and 1.0 g triple super phosphate, treated with varying amounts of gum arabic, and seeded with sorghum. Water was applied in the same manner as for the evaporation experiments.

A preliminary trial to observe the effects of gum arabic on seedling growth was conducted with 0, 5, 10, 15, 20, 25, 50, and 100 g gum arabic per pot with four replicates per treatment. The experiment was seeded on 21 January and harvested on 20 February. The weather was cool at this time which caused a slow rate of growth. The above treatments produced 0.65, 0.81, 0.88, 0.51, 0.14, 0.30, 0.01, and 0.14 g dry matter (shoot weight) per pot, respectively. It was obvious that gum arabic treatment above 20 g per pot was injurious to seedling growth. Visual observations made during this trial showed that the gum formed a crust on the surface and the strength of this crust increased with increasing amount of the gum. The

increaed strength of the crust affected water penetration, seedling emergence, and stem expansion. Whether there was any phytotoxic effect could not be ascertained. Consequently, in subsequent trials, gum arabic treatments of 0, 5, 10, 15, and 20 g per pot were used.

EVAPORATION EXPERIMENT: Pots were filled with 4.016 kg goz sand treated with 0, 5, 10, 15, and 20 g powdered gum arabic. Each treatment was replicated three times. After the water content was brought to 716 g per pot, the pots were exposed to evaporation. No drainage was observed. Cumulative loss of water was obtained by weighing of the pots on a toploading Mettler balance. Water losses measured in units of g were considered numerically equal to volumes in $cm^3$ and converted to depth basis by dividing the volumes by the cross sectional area of the soil surface.

Two pots without holes in the bottom were filled with free water to the same level as the soil surface. These pots were exposed to evaporation in order to obtain an estimate of the daily variations in evaporative conditions. Free water surface was raised to the original level after each weighing.

After eight days of evaporation pots with soil were rewetted with 716 g of water. Some structural change had occurred, particularly the cracks at the interface between the soil and the pot walls. As a result, several of the pots showed drainage indicating that the initial water content could not be held at 716 g. The initial water content was then reduced to 616 g for the second drying cycle.

Aging and wetting-drying, a natural process under field conditions, could have an effect on the moisture conserving property of the gum arabic. Another trial was conducted in which four sets of 5 pots, each with 10 g gum arabic treatment, were prepared on 19 April, 23 April, 7 May, and 23 May. Each set was exposed to evaporation immediately after the initial wetting. 100 to 200 g water was applied to the pots at three to four day interval. Thus, a longer aging period also meant more wetting-drying sequences. On 31 May all pots were rewetted to the same water content (616 g per pot) and exposed to evaporation. Evaporative loss of water was measured by daily weighing over a period of seven days.

PLANT GROWTH EXPERIMENT: Twelve pots of each treatment were prepared, fertilized, seeded with 10 seeds of sorghum variety Gadam El Hammam on 26 February, and exposed to evaporation. When the seedling growth reached about 5 cm height the plant population was reduced to 3 plants per pot. Watering continued at frequent intervals. The amount of water applied in any given watering was either 100 g or 200 g and was estimated to be no more than 60 per cent of free water evaporation from similar size pots. All pots were watered at the same time and received the same amount of water.

Seedling growth was measured on 10, 15, 20, and 25 March. On each of the dates, measurements were made on three randomly selected pots from each treatment. Plants were cut at the ground level and their fresh and dry weights were determined.

## RESULTS

Effects of gum arabic on cumulative evaporation are shown in Figures 1 and 2. Data in both the Figures show that evaporation decreases with increasing amounts of gum arabic. Figure 1 shows evaporative losses of water during the first drying cycle with initial water content of 716 g per pot while Figure 2 shows the losses during the second drying cycle with initial water content of 616 g per pot. The purpose of observing a second drying cycle was to see if the effect of gum changed as a result of drying and aging. However, a direct inference about the changes in the effects of the gum cannot be made, because of differences in the initial water content and in atmospheric evaporativity from the first to the second drying cycle. Nevertheless, a comparison of data in both the Figures shows that during the first drying cycle, water saving per unit gum applied was maximum for the first 5 g treatment. Further 5 g increments did not retard evaporation as much as the first increment. Incremental effects of gum on evaporative losses of water were larger during the second drying cycle. Data for both the cycles show that incremental benefits were minimal when gum application was increased from 15 to 20 g per pot.

Effects of aging and wetting-drying were observed for the treatment with 10 g gum arabic per pot. Cumulative evaporation data for pots aged to various lengths of time are presented in Table 1. Data show that evaporation was maximum for the pots aged to 8 days before starting the final drying cycle. Minimum evaporation was

obtained for the pots aged to 24 days. Aging to 38 and 42 days caused the evaporation to increase slightly over the minimum. The trend appears to be that effectiveness of the gum arabic increases with aging to a certain point and then it begins to decrease. However a closer look at the data indicates that the differences in evaporation values for the 24, 38, and 42 day aging periods are only slight and may not be significant. On the other hand, evaporative losses for the 8 day aging period are perceptibly higher than those for the 24, 38, and 42 day aging periods. It may be that effectiveness of gum arabic increases with time after application and levels off at some point.

Sorghum dry matter (shoot growth) data obtained on 10, 15, 20, and 25 March are presented in Figure 3. The rate of growth was better than observed in the preliminary experiment since temperatures were higher. During the early stages of growth treatment differences were minor. The control and the 5 g treatments showed slightly better initial growth, possibly due to early emergence and less restrictive conditions for root and stem expansion. As the time progressed, effects of moisture deficiency became more important and treatments with higher gum arabic had better growth. Wilting occurred in the pots with no gum, then in the pots with 5 g gum, and so on. Differences between treatments became much more visible by 15 March and by 20 March beneficial effects of the gum were clearly evident. However, there was little difference between the growth in pots receiving 15 g and 20 g gum. Data presented in Figure 3 are rearranged in Figure 4 to show the progression of accumulation

of dry matter with time. It is clear that dry matter accumulation increased with time for all treatments. However, it remained perceptibly lower for the control.

## DISCUSSION

Results presented in this report show that gum arabic is effective in retarding evaporation from sandy surfaces and that water saved in this manner is beneficial to seedling growth and establishment. It is also apparent that only small concentrations of gum are useful for early plant growth. Larger concentrations result in crusts of higher mechanical impedance which affect, adversely, seedling emergence and stem expansion. The mechanisms of reactions between the gum arabic and the sand grains are not clear at this point. Visual observations suggest that a simple physical binding of the sand grains occurs resulting in a barrier of some porosity. The porosity of this barrier at low concentrations appears to be high enough that seedling emergence and water infiltration are not affected materially. The binding of sand grains suggests that gum arabic applications could also be effective in preventing soil movement due to wind action.

The movement and persistence of the gum in the soil have not been studied. The powdered gum appears to dissolve readily when water is added to the treated dry soil. However, it is quite possible that dissolution of the gum is not complete with the first appli-

cations of water. Observations on the effects of aging and wetting-drying (Table 1) show a time dependent increase in the effectiveness of the gum. It is probable that amount of the sand grains bonded by the gum increases as the gum dissolves more and spreads between the sand grains. An eventual decrease in the amount of bonds or bond strengths may also result from probable chemical changes and microbial action.

Relative advantages of applications of gum arabic in powder form or as sprays in solution form are not known. Visual observations indicated a rather rapid drying out of the dissolved gum suggesting that movement of the gum may be very limited and may be taking place only when sufficient moisture is present. If the beneficial effects are only due to a film on the surface, then spraying dilute solutions may be equally effective in retarding evaporation. Spraying should require lesser amount of gum and the uniformity of application should also be better. Powder form was given preference in the present experiment because it was thought that availability of water and spray equipment would be a problem at the farmers' level

The decision to conduct this experiment in pots resulted from circumstances beyond control. Field facilities were unavailable and conditions for growing plants out in the field were unfavorable. It was thought that pots could provide valuable information for future field testing of gum arabic and further extension of research. No doubt, the information obtained shows the potential of this material. However, since growing conditions in a pot are markedly

different from those in the field, a discussion of the limitations of pots encountered in the present experiment appears warranted.

Our premise was that gum arabic would retard evaporation and help in seedling growth and establishment. It did. However, increased growth in the treated pots also led to an increase in transpiration demand which the limited pot water volume could support only for a short time. As a result, plants that grew well initially began to show frequent wilting later. The delay in onset of wilting was proportional to the amount of gum added. It was considered essential to continue growth to some level until measurable dry matter had accumulated. For this reason pots were watered sparingly. But a point came when it became impossible to maintain plant turgidity without daily watering. Since all pot had to be watered with the same amount of water and with the same frequency, the earliest affec- plants with much less leaf area began to benefit more because of their lower transpiration demand. This limited the life of the experiment and the extent to which treatment differences could be demonstrated. A field experiment, therefore, seems essential for evaluating the effects of gum arabic on plant growth. Under the field conditions, an early establishment of seedlings should give the plant a continuous advantage because of unlimited soil volume for root extension and moisture extraction.

The amount of gum producing the best results in pot experiments is about 10 to 15 g per pot. This would appear to be a large amount if field applications are calculated on the basis of the amount of

potted soil or the cross sectional area of the pots. It is, however, possible to treat only the planted hills or the rows only. Or, apply only a fraction of the amount indicated for the best results. Spraying should require smaller amounts of the gum. A five per cent solution covering a one hectare field to a depth of 1 mm should require 50 kg of gum arabic. At current prices ( approximately 45 Sudanese Pounds per 100 lb) the cost would be 56 Sudanese Pounds per hectare. Reject gums and those below the premium grade should cost less. But since field conditions are different and atmospheric evaporativity is milder during the rainy season when crops are grown, a discussion of optimum amounts and costs must await results from field trials.

In addition to determining optimum amount, method and timing of application, and persistence of the gum in the soil are important areas of research. It may also be worthwhile to explore fortification of the gum with other locally available materials such as clay soil. Goz sands are almost pure sands. Introducing small amounts of clayey soil might enhance the effectiveness of the gum.

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## CAPTIONS FOR TABLES

Table 1. Effects of aging and wetting-drying on evaporative loss of water from potted goz sands treated with 10 g of gum arabic per pot.

## CAPTIONS FOR FIGURES

Figure 1. Effect of gum arabic on evaporative loss of water from potted goz sands. The initial water content was 716 g per pot and the total free water evaporation over an 8-day period was 102 mm.

Figure 2. Effect of gum arabic on evaporative loss of water from potted goz sands (second drying cycle). The initial water content was 616 g per pot and the free water evaporation over an 8-day period was 123 mm.

Figure 3. Effect of gum arabic on sorghum seedling growth in potted goz sands. Numbers by each curve are dates of observation.

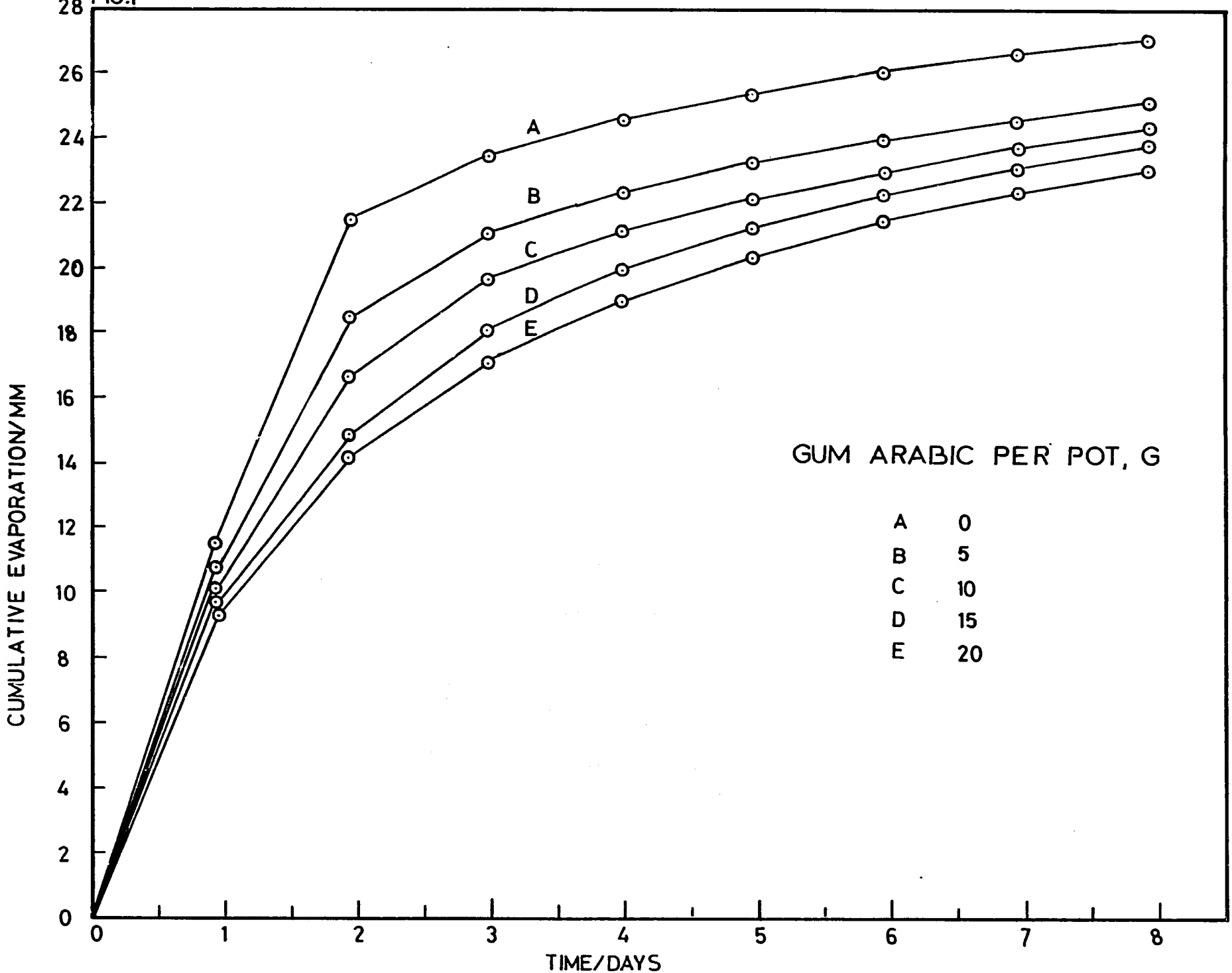
Figure 4. Sorghum seedling growth as a function of time as affected by gum arabic treatment.

Table 1. Effects of aging and wetting-drying on evaporative loss of water from potted goz sands treated with 10 g of gum arabic per pot.

| Aging period (days) | Days since zero time | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0.87 | 1.88 | 2.88 | 3.94 | 4.92 | 5.91 | 6.94 |
| | Cumulative evaporation, mm* | | | | | | |
| 8 | 4.75 | 10.22 | 13.73 | 15.22 | 16.03 | 16.67 | 17.38 |
| 24 | 4.03 | 7.41 | 9.86 | 11.44 | 12.44 | 13.31 | 14.32 |
| 38 | 4.39 | 8.42 | 11.14 | 12.73 | 13.71 | 14.49 | 15.43 |
| 42 | 4.71 | 9.51 | 12.01 | 13.37 | 14.21 | 14.89 | 15.71 |

* Mean of 5 pots

FIG.1


CUMULATIVE EVAPORATION/MM
TIME/DAYS
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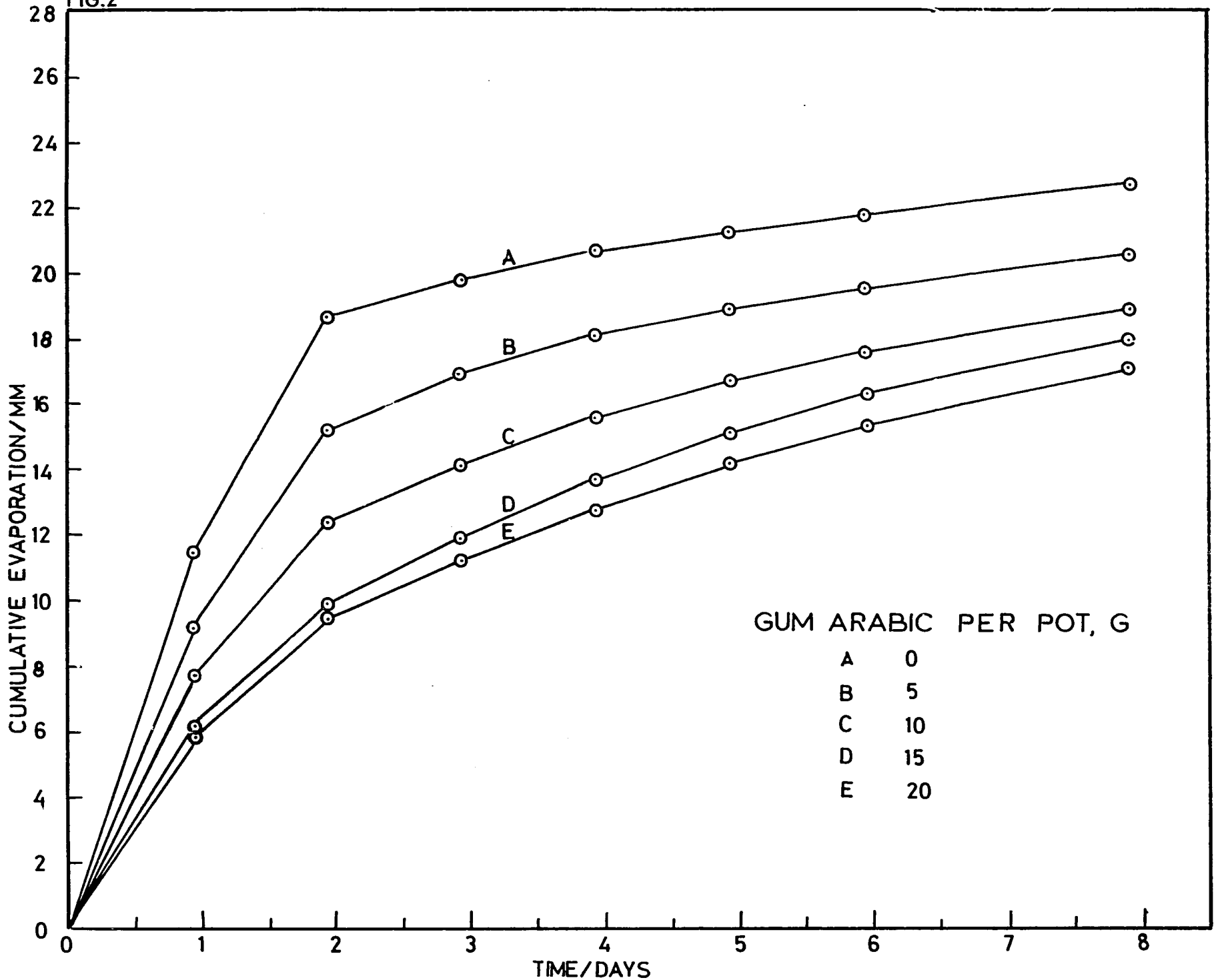
2
4
6
8
10
12
14
16
18
20
22
24
26
28
0
1
2
3
4
5
6
7
8
A
B
C
D
E
GUM ARABIC PER POT, G
A 0
B 5
C 10
D 15
E 20

FIG.2


CUMULATIVE EVAPORATION/MM
TIME/DAYS
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2
4
6
8
10
12
14
16
18
20
22
24
26
28
0
1
2
3
4
5
6
7
8
A
B
C
D
E
GUM ARABIC PER POT, G
A 0
B 5
C 10
D 15
E 20

FIG.3

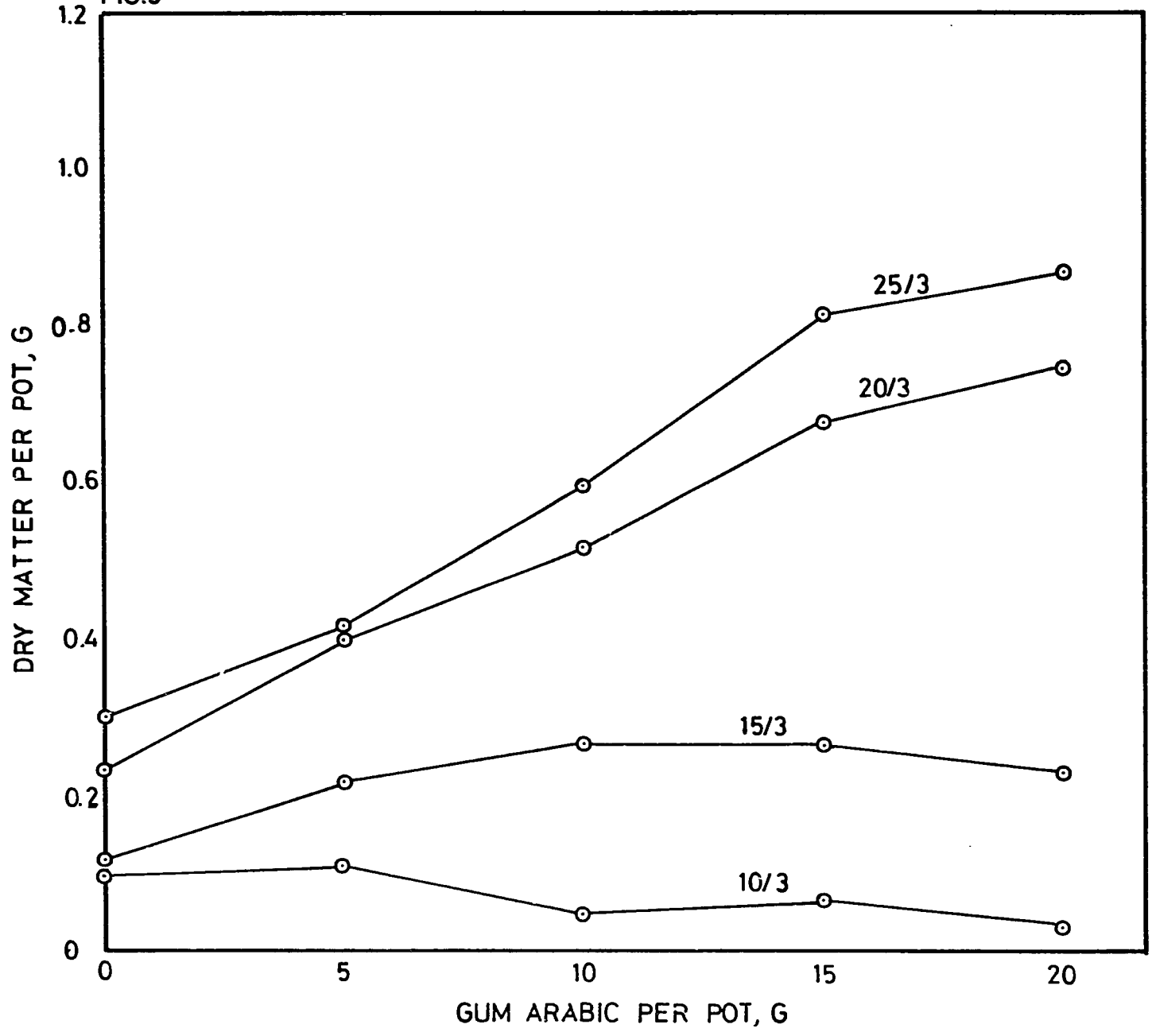
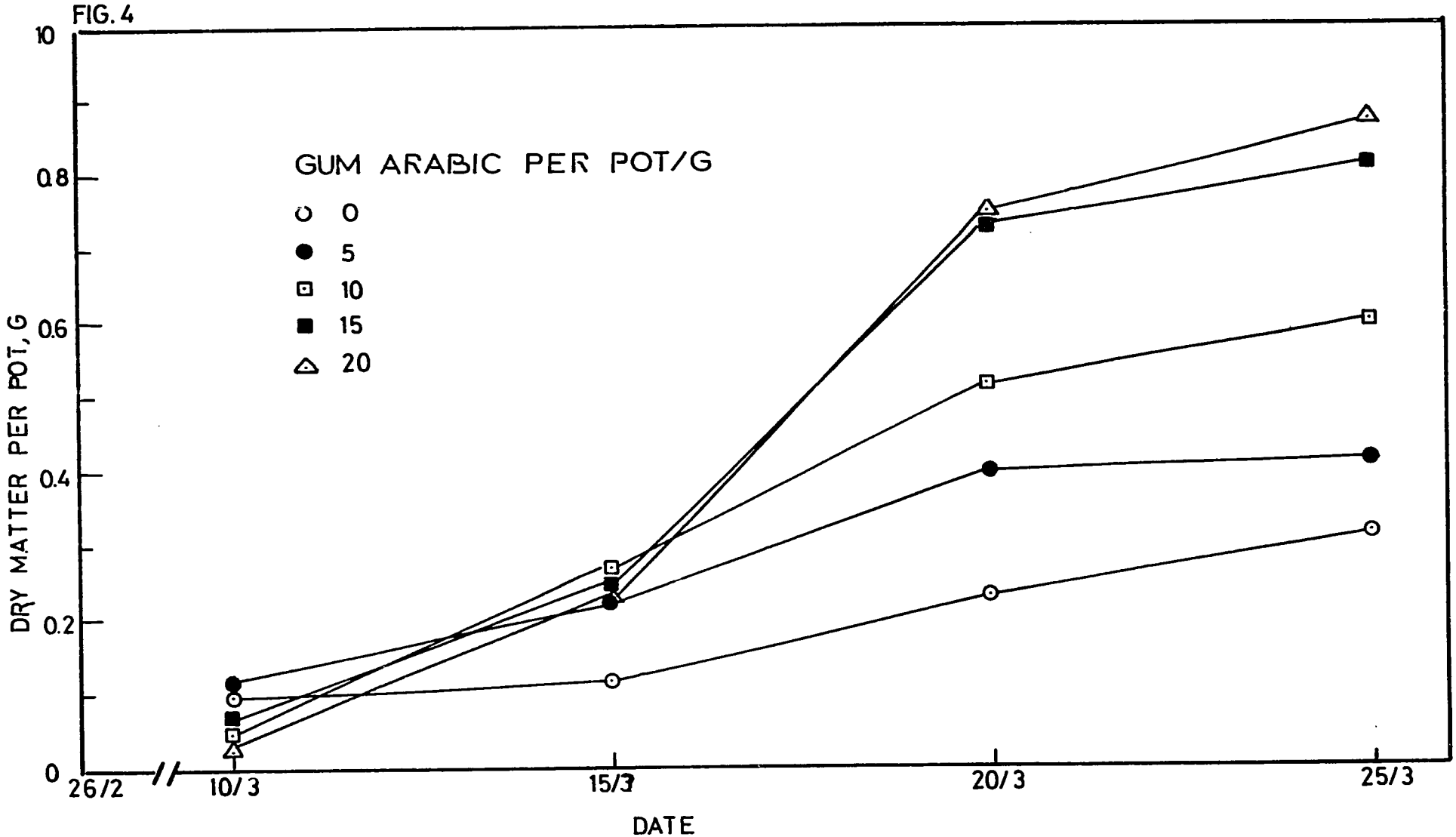

1.2
1.0
0.8
0.6
0.4
0.2
0
DRY MATTER PER POT, G
25/3
20/3
15/3
10/3
0
5
10
15
20
GUM ARABIC PER POT, G

FIG. 4


GUM ARABIC PER POT/G
0
5
10
15
20
DRY MATTER PER POT, G
10
0.8
0.6
0.4
0.2
0
26/2
10/3
15/3
20/3
25/3
DATE