Influence of Soil Moisture Stress on the Nitrogen Nutrition and Grain Productivity of Mungbean

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Plant growth and grain yield of leguminous crops are largely affected by the climatic factors as well as the acidity and fertility of the soil^{1,5,8}). The soil moisture content was also known to affect the grain yield⁴). Mungbean is a short-season crop which is usually grown in the drained paddy field where it makes use of residual nutrients and water after rice cropping without irrigation^{2,9,11}). Mungbean, therefore, would be occasionally imposed by drought during its growing period. The grain yield of mungbean is generally lower than that of other grain legumes such as soybean and peanut^{2,3,9,11}). The reasons would be due to the cropping systems as described before as well as the insufficient management in cultivation, in which the irrigation management is partly concerned. However, the watery characteristic of mungbean plant remains unknown due to the lack of literature on the grain productivity and soil moisture.

Accordingly, the effects of different soil moisture levels on the grain productivity of some grain legumes including mungbean were firstly compared and then the plant growth, grain yield as affected by wilting at different growth stages of mungbean were also investigated under soil pot culture conditions.

Materials and Methods

1. Fertilizer application and plant sampling

The chemical properties of the soil have been reported in our previous papers^{11,15}). As basal dressing, 2.0, 5.0 and 2.0 g of urea, superphosphate and potassium chloride were well-mixed with the soil in 1/2,000a Wagner pots while 0.5, 2.0 and 0.5 g of the above fertilizers were applied to the soil in 1/5,000a

Wagner pots respectively before sowing. Experimental designs comprised four replicates for Experiment 1 and three replicates for Experiment 2, and the data were their averages respectively. The methods of plant sampling, nitrogen analysis and acetylene reducing assay were the same as reported previously^{11,14,16}).

2. Plant culture

Experiment 1: The seeds of four legumes, mungbean (Raipur local variety, India), adzuki bean (early maturing type), peanut (erect type) and soybean (cultivar Okuhara) were sown in 1/2,000a Wagner pot and thinned out to three uniform seedlings two weeks after germination. Tensiometers were used to determine the soil water potential and also the time of irrigation. Four different irrigations (pF 0 to 1.5, 0 to 2.0, 0 to 2.5 and 0 to 2.8) were prepared when the first trifoliate leaves of each legume were fully developed. In those treatments, the pot soil was watered when the pF reached to 1.5, 2.0, 2.5 and 2.8 respectively. These irrigation treatments were repeated throughout the growth cycles of each legume⁷).

Experiment 2: Mungbean seeds (Raipur local variety, India) were sown and grown in 1/5,000a Wagner pots. Wilting treatment was carried out at five different growth stages, i.e. early flowering, fully flowering, podding, pod developing and grain maturing stages. Each potted-plant was grown under fully irrigated condition until the wilting treatments as described above, respectively. The wilting treatment of potted-plants was carried out by interruption of irrigation. Potted-plants with wilting on the last fully developed trifoliate leaves were not subsequently irrigated for two days, and then

rewatered and successively grown until the harvest of pods derived from first flowering stage.

Results and Discussion

1. Grain productivity of some grain legumes as affected by different soil moisture levels:

Table 1 shows the plant dry matter and total nitrogen yield of various legumes which were grown under different water irrigation conditions. The grain and grain nitrogen yields showed maximum in plot A, in which an adequate watering was provided. The yields generally showed a declining tendency with the restriction of watering though these decreasing rates were varied from crop to crop.

Fig. 1 shows the relative grain yield of other treatments to that of plot A. Mungbean and adzuki bean maintained relatively high yields even in severe water stress plot (pF 0 to 2.8, plot D) while the yield of peanut decreased and was only 1/4 in comparison to that of plot A (pF 0 to 1.5). Peanut is well-known as a drought resistant plant, but its low grain yield was mainly

considered due to the less penetration of genophores into soil and also due to the less development of young pods under soil water deficit condition⁹⁾. The response of soybean

Fig. 1. Effect of different water irrigations on the relative values of grain yield of some legumes.

Table 1. Effect of different water irrigations on the plant dry matter and total nitrogen accumulated into plant of some legumes.

Legume	Soil moisture (pF)	Dry matter (g/pot)		Total nitrogen (mg/pot)	
		Grain	Total plant	Grain	Total plant
Mungbean	A. 0—1.5	9.8	24.3	334	471
	B. 0—2.0	9.1	25.7	338	536
	C. 0—2.5	7.6	20.7	294	475
	D. 0—2.8	8.9	21.0	330	493
Adzuki bean	A. 0—1.5	11.3	26.2	388	584
	B. 0—2.0	8.4	20.9	286	483
	C. 0—2.5	9.3	21.7	341	501
	D. 0—2.8	9.3	18.7	327	485
Peanut	A. 0—1.5	6.3	26.3	202	355
	B. 0—2.0	2.9	21.5	106	279
	C. 0—2.5	2.1	18.4	75	249
	D. 0—2.8	1.6	21.3	63	295
Soybean	A. 0—1.5	10.8	21.9	561	693
	B. 0—2.0	8.9	17.2	453	535
	C. 0—2.5	9.5	18.8	491	594
	D. 0—2.8	5.6	11.2	285	359

Fig. 2. Effect of different water irrigations on the efficiencies of grain and grain protein production of some legumes.

was intermediate between peanut and mungbean and adzuki bean.

The dry matter and total nitrogen accumulated into each plant also decreased similarly with decrease in soil moisture content except for the high values of mungbean in weak stress plot (pF 0 to 2.0, plot B, Table 1). It is suggested from this phenomenon that mungbean was able to grow and produce high grain yield under wide range of soil water regime compared to other grain legumes.

Fig. 2 shows the efficiencies of grain and grain protein production^{12,13)} as they were affected by the different water irrigations. It was recognized that the efficiency of grain protein production was always higher than that of grain production^{12,13)} and the efficiencies of peanut markedly decreased with the degree of water stress. However, a noteworthy relationship between the efficiencies and soil moisture content was not observed on other legumes except for a slight increase in both efficiencies of mungbean and adzuki bean at severe soil moisture deficiencies (pF 0 to 2.8, plot D). It seemed that such favorable characteristic of the above two legumes was associated with the

Table 2. Effect of different water irrigations on the grain properties of some legumes.

Legume	Soil moisture (pF)	Thousand grain weight (g)	Crude protein content (%)
Mungbean	A. 0—1.5	42	21.4
	B. 0—2.0	44	23.2
	C. 0—2.5	49	24.2
	D. 0—2.8	46	23.3
Adzuki bean	A. 0—1.5	79	21.4
	B. 0—2.0	64	21.2
	C. 0—2.5	85	22.9
	D. 0—2.8	89	22.1
Peanut	A. 0—1.5	332	20.2
	B. 0—2.0	322	22.8
	C. 0—2.5	300	22.9
	D. 0—2.8	320	25.1
Soybean	A. 0—1.5	220	32.4
	B. 0—2.0	241	31.9
	C. 0—2.5	226	32.2
	D. 0—2.8	207	31.9

Table 3. Effect of temporary wilting at different growth stages on the grain yield and grain properties of mungbean.

Stage of wilting	Plant growth stage					Grain		Thousand grain weight (g)	Crude protein content (%)
	EF ^a	F ^b	P ^c	PD ^d	M ^e	Yield (g/pot)	Number (No./pot)		
Early flowering ^a	w					2.6 (23)*	59	44.1	22.76
Flowering ^b		w				2.4 (21)	57	42.5	24.73
Podding ^c			w			3.4 (30)	82	42.0	22.89
Pod developing ^d				w		7.9 (71)	188	42.2	20.64
Grain maturing ^e					w	8.5 (76)	219	38.8	19.97
Non-wilting						11.2 (100)	257	43.5	20.78

* Number in parenthesis shows relative value to that of non-wilting treatment.

w Wilting treatment.

Table 4. Effect of temporary wilting at different growth stages on the grain components of mungbean.

Stage of wilting	Podding (No./pot)	Matured grain	
		No./pod	g wt./pod
Early flowering	7.0	8.4	0.37
Flowering	8.0	7.1	0.30
Podding	9.7	8.5	0.35
Pod developing	16.0	11.8	0.50
Grain maturing	20.3	10.8	0.42
Non-wilting	23.0	10.7	0.47

higher productivity of their grain yields at water stress conditions.

The grain properties of the four legumes as affected by different water irrigations are shown in Table 2. There were not recognized a clearly tendency though the thousand grain weight and crude protein content of mungbean as well as of adzuki bean seemed to increase a little when the plants were grown in low soil moisture regime.

2. Effect of wilting treatment at different growth stages of mungbean:

As described above, mungbean is

Fig. 3. Effect of temporary wilting at different growth stages on the plant dry matter and total nitrogen of mungbean.

G: Grain; T: Other aerial plant parts.

EF: Early flowering; F: Flowering;

P: Podding; PD: Pod developing;

M: Grain maturing stage; C: Control (non-wilting).

classified as a leguminous crop which grows well in a wide range of soil moisture regime in compared to other grain legumes. However, it is considered that mungbean is occasionally imposed to the severe drought during its growing period under natural condition, and consequently, its grain productivity is also affected^{6,10}.

Table 3 shows the grain yield and grain properties of mungbean under the wilting

Table 5. Effect of temporary wilting at different growth stages on the acetylene reducing activity of mungbean.

Stage of wilting	Acetylene reducing activity ($\mu\text{M C}_2\text{H}_4/\text{h}/\text{pot}$)	
	Before treatment	After treatment
Early flowering	7.39 (100)*	0.18 (2.4)*
Flowering	12.84 (100)	0.17 (1.3)
Podding	22.43 (100)	0.27 (1.2)
Pod developing	18.60 (100)	0.08 (0.4)
Grain maturing	26.89 (100)	0.68 (2.5)

* Number in parenthesis shows relative value to that of before treatment plot.

treatments which were carried out at different periods of growth. The grain yield was decreased by wilting treatment at all growth stages, particularly in flowering and podding stages. After that time, the decreasing rate in grain yield was orderly smaller in later wilting treatment. Similar tendency was recognized in number of grains harvested though the grain properties such as thousand grain weight and crude protein content were almost unaffected.

Table 4 shows the variation in podding and grain components of mungbean affected by wilting at different growth stages. The pod number per pot, i.e. per plant was markedly decreased by wilting at flowering and podding stages. The same tendency was observed on grain number and grain weight per pod although the degree of decrease was lower than the above.

Consequently, it was concluded that wilting caused the most inhibitory effect at flowering stage of mungbean, and the decline in grain yield was mainly due to the decrease in number of pods and was secondly due to the decreased grain weight per pod. The decrease of pod number induced by the wilting treatment was presumed to depend on the flower and pod shedding. In addition, the retardation of grain enlargement in pods acted on the decrease of grain productivity in mungbean.

Fig. 3 shows the plant dry matter and total nitrogen accumulated into plant which lowered by wilting treatment. Its decreasing rates were considered to be larger when the

Fig. 4. Effect of temporary wilting at different growth stages on the efficiencies of grain and grain protein production of mungbean.

$$A : \frac{\text{Grain yield}}{\text{Dry weight of plant top}} \times 100$$

$$B : \frac{\text{Total nitrogen in grain}}{\text{Total nitrogen in plant top}} \times 100$$

EF : Early flowering ; F : Flowering ;

P : Podding ; PD : Pod developing ;

M : Grain maturing stage ;

C : Control (non-wilting).

wilting treatment was carried out at earlier growth stage. This treatment also affected the nitrogen uptake and nitrogen fixation by the plant. Nitrogen fixation is well-known as the most important function in leguminous crops. The nitrogen fixing activity treated with wilting treatments at different growth stages was measured by acetylene reduction method and shown in Table 5. In comparison with those of the non-treated plants, these activities became almost zero after wilting treatment at all growth stages. This implied that wilting treatment, particularly at early growth stage, brought about a strong inhibitory effect on nitrogen accumulation through the depression of nitrogen fixing activity. Therefore, it was assumed from these results that the influence of wilting, particularly treated at early growth stages on the nitrogen uptake from soil and nitrogen fixation were not temporarily but it extended throughout to the later growth stage and subsequently affected the grain productivity.

The efficiencies of grain and grain protein production (Fig. 4) also showed similar tendency to those of grain yield, plant dry matter and total nitrogen. Therefore, it was thought that the decrease in grain yield of

mungbean by wilting, particularly at early growth stage, was partially due to the decrease in its production efficiencies.

Consequently, it was clear from this investigation that wilting at prior to podding stage reduced markedly grain yield and production efficiencies of mungbean. It was desirable to pay much attention on the irrigation management for the cultivation of mungbean, particularly at early growth stages.

Summary

The soil pot cultures were carried out to investigate the relationship between plant growth of some leguminous crops and different soil moisture regimes with special reference in mungbean, and further, investigate the effect of wilting at different growth stages of mungbean on its nitrogen nutrition and grain productivity. The results obtained were summarized as follows :

1) The grain yield, plant dry matter and total nitrogen of leguminous crops decreased with the restriction of water supply but the rates of decrease in mungbean were lower than that of other legumes such as soybean and peanut.

2) The efficiencies of grain and grain protein production of mungbean were almost unaffected by soil moisture levels while those of peanut were markedly decreased according to the decrease of soil moisture content.

3) On the other hand, mungbean plants with severe wilting at all growth stages decreased its grain yield, plant dry matter, total nitrogen, nitrogen fixing capacity and also production efficiencies. It is observed that the inhibitory effect was obviously high in the plants treated at flowering and podding stages.

4) The low grain yields obtained were mainly caused by the decrease of pod number per plant and secondly due to the decrease of grain weight per pod.

5) It was clarified from this investigation that the irrigation management for the cultivation of mungbean, particularly at early growth stages should be paid much attention in expectation to maintain the high grain yield and production efficiencies of mungbean.

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〔和 文 摘 要〕

リョクトウの窒素栄養および子実生産に及ぼす土壤水分欠乏の影響

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数種のマメ科穀実作物を異なる水分供給条件下でポットで土耕栽培し、その影響を調査した。さらに、生育の異なる段階にあるリョクトウに萎凋処理を行い、生育、収量に及ぼす土壤水分欠乏の影響をとくに窒素栄養と関連させて調査した。その結果、下記のことことが明らかとなった。

1. 各種マメ科穀実作物の子実収量、植物体乾物重、全窒素量は土壤への水分供給が制限されるに伴って低下するが、リョクトウにおける低下度合はダイズやラッカセイなどに比べて小さかった。
2. リョクトウの子実生産効率や子実タンパク生産効率は土壤への水分供給の制限によってほとんど影響を受けないが、ラッカセイでは水分供給の制限に伴い急激に低下した。
3. リョクトウに対する萎凋処理はいずれの生育段階においても、子実収量、植物体乾物量、全窒素量、窒素固定能および生産効率に対して抑制的に働くが、その抑制度合は開花期——莢形成期の処理において最も強かった。
4. 萎凋処理に伴う子実収量の低下は着莢数や莢当りの子実重の減少に基因するが、着莢数の減少が最も主要な要因として働いていた。
5. これらの結果から、リョクトウの栽培に際し、着莢期以前の萎凋が子実収量や生産効率を顕著に抑制するためにとくに同時期での水管理に留意すべきである。