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

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As previously observed, mungbean is able to grow well in a wide range of soil moisture regime in comparison with other grain legumes though it may be damaged and decreased the grain productivity by severe wilting temporarily at all growth stages of its growing period\(^1\). Considering to its general cultivation in paddy fields after rice cropping in tropical regions, mungbean would be occasionally caught in excess soil moisture throughout its growing process\(^6,10,15\). As contrary to rice crop, the leguminous crops were considerably damageable by excess soil moisture due to the poor differentiation of its pneumatic system\(^1,2,3\). In addition, it was natural that the excess of soil moisture as same as the deficiency was thought to affect the growth and grain yield of mungbean\(^7,17\). Such responses of mungbean plant to excess soil moisture were also considered to vary according to the different growth stages\(^17\).

Accordingly, the effect of waterlogging on the grain productivity and nitrogen nutrition of mungbean was investigated under soil pot conditions.

Materials and Methods

Mungbean seeds (Raipur local variety, India) were sown in 1/5,000a Wagner pot containing 4 kg of mineral soil with a basal dressing as in our previous papers\(^15,17\). After thinning out, three seedlings in each pot were grown by using common method in glasshouse. In an initial experiment, the pots with mungbean at the first flowering stage were waterlogged for 1, 2, 3 or 4 consecutive day respectively. After the treatments, nitrogen fixing activity was investigated. In a second experiment, the potted-plants were successively grown until the harvest of pods derived from first flowering stage. During the growing process, the mungbean pots were waterlogged for three days at each of five growth stages, i.e. early flowering, fully flowering, podding, pod developing and grain maturing stages. Three pots were subjected to sampling and the methods of plant sampling, nitrogen analysis and acetylene reducing assay were as reported previously\(^15,17,19\).

Results and Discussion

According to previous experiment on leguminous crops, mungbean was able to grow and highly maintain its grain productivity in a wide range of soil moisture regime\(^17\). However, the adaptability of mungbean to excess moisture status was not investigated. Thus, the investigation on the

Fig. 1. Effect of waterlogging on the acetylene reducing activity of mungbean root nodules at first flowering stage.
growth and grain productivity of mungbean as affected by excess moisture in soil was carried out. In general, the leguminous crops were damageable by excess soil moisture due to the poor differentiation of its pneumatic system

In Japan, the grain productivity of soybean on drained paddy field was reported to be frequently low in high-rain year due to its weak resistance to excess soil moisture. It is presumed that the main limiting factor on growth will be the deficiency of oxygen supply into the root system.

Fig. 1 shows the nitrogen fixing activity which was one of the most important function in leguminous crop. The investigation was carried out at flowering stage by using acetylene reduction method. Acetylene reducing activity gradually decreased by waterlogging and was almost zero after three days of treatment. It is well-known that the leghaemoglobin containing in nodules highly correlates with the appearance of nitrogen fixing activity. In fact, the leghaemoglobin level was observed to decrease according to length of period of waterlogging, similar to nitrogen fixing activity in this experiment (Table 1). It implies that the waterlogging interfere with the nitrogen fixing capacity of effective nodules through the degradation of leghaemoglobin in addition to the decrease of oxygen supply to root system. The recovery of nitrogen fixing activity of injured nodules damaged by excess soil moisture was not studied in this experiment but waterlogging brought about the transformation in morphology and decay of root nodules. Therefore, the immediate recovery of nodule function as a source of nitrogen supply would be impossible. However, no external damage was visible on the aerial part of plants even in the severe waterlogging treatments.

As mentioned above, excess soil moisture had inhibitory effects on symbiotic nitrogen fixation of leguminous crops. It was assumed therefore that the effects on nitrogen fixation might extend to grain productivity of mungbean as well.

The effect of waterlogging was also considered to vary according to the different growth stages of mungbean. Accordingly, the treatment of three days waterlogging at five

Table 1. Change of leghaemoglobin in mungbean root nodules after waterlogging treatment.

<table>
<thead>
<tr>
<th>Waterlogged period (day)</th>
<th>Leghaemoglobin (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>96.7</td>
</tr>
<tr>
<td>1</td>
<td>96.7</td>
</tr>
<tr>
<td>2</td>
<td>76.7</td>
</tr>
<tr>
<td>3</td>
<td>61.7</td>
</tr>
<tr>
<td>4</td>
<td>8.3</td>
</tr>
</tbody>
</table>

* Percentage to 30 nodules (>2 mm in size) of respective treatment.

Table 2. Effect of 3 days waterlogging at different growth stages on the grain yield and grain properties of mungbean.

<table>
<thead>
<tr>
<th>Stage of waterlogging (3 days)</th>
<th>Plant growth stage</th>
<th>Grain Yield (g/pot)</th>
<th>Number (No./pot)</th>
<th>Thousand grain weight (g)</th>
<th>Crude protein content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early flowering</td>
<td>F</td>
<td>7.0 (41)*</td>
<td>175</td>
<td>40.1</td>
<td>20.92</td>
</tr>
<tr>
<td>Flowering</td>
<td>F</td>
<td>3.0 (18)</td>
<td>79</td>
<td>38.4</td>
<td>20.94</td>
</tr>
<tr>
<td>Podding</td>
<td>F</td>
<td>6.9 (40)</td>
<td>145</td>
<td>47.3</td>
<td>22.93</td>
</tr>
<tr>
<td>Pod developing</td>
<td>F</td>
<td>10.3 (60)</td>
<td>220</td>
<td>46.9</td>
<td>23.19</td>
</tr>
<tr>
<td>Grain maturing</td>
<td>F</td>
<td>14.2 (83)</td>
<td>302</td>
<td>46.9</td>
<td>22.31</td>
</tr>
<tr>
<td>Non-waterlogging</td>
<td>F</td>
<td>17.1 (100)</td>
<td>321</td>
<td>53.3</td>
<td>22.42</td>
</tr>
</tbody>
</table>

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

W Waterlogging treatment.
Table 3. Effect of 3 days waterlogging at different growth stages on the grain components of mungbean.

<table>
<thead>
<tr>
<th>Stage of waterlogging (3 days)</th>
<th>Poddng (No./pot)</th>
<th>Matured grain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Poddng (No./pot)</td>
<td>Matured grain</td>
</tr>
<tr>
<td>Early flowering</td>
<td>16.7</td>
<td>10.5</td>
</tr>
<tr>
<td>Flowering</td>
<td>9.0</td>
<td>8.8</td>
</tr>
<tr>
<td>Poddng</td>
<td>14.0</td>
<td>10.4</td>
</tr>
<tr>
<td>Pod developing</td>
<td>24.0</td>
<td>9.2</td>
</tr>
<tr>
<td>Grain maturing</td>
<td>30.7</td>
<td>9.8</td>
</tr>
<tr>
<td>Non-waterlogging</td>
<td>33.7</td>
<td>9.5</td>
</tr>
</tbody>
</table>

Fig. 3. Effect of 3 days waterlogging at different growth stages on the acetylene reducing activity of mungbean.

A: Before waterlogging; B: After waterlogging.
EF: Early flowering; F: Flowering; P: Poddng; PD: Pod developing; M: Grain maturing stage.

60 and 83% when the plants were waterlogged at podding, pod developing and grain maturing stages respectively. A similar tendency was observed on the number of grains. The grain properties such as thousand grain weight and crude protein content were also affected and they showed relatively low values at the plants with waterlogging at vegetative growth stage.

Table 3 shows the variation in poddng and grain components of mungbean. The number of grains per pod was almost unaffected by waterlogging treatments, while the pod number per pot, i.e. per plant and grain weight per pod decreased significantly, especially in the former. It was assumed that the decrease in grain productivity as a result of waterlogging treatment was mainly due to the decrease in number of the pods and was secondly due to the decrease of grain weight per pod. Although detailed observation was not carried out, the decrease of pod number by waterlogging was surely dependent on the flower and pod shedding. In addition to that, the retardation of grain thickening in pods also acted on the decrease of grain productivity in mungbean. These phenomena were very the same as the responses of severe wilting as reported previously.

Fig. 2 shows the plant dry matter and total nitrogen of mungbean plants treated with waterlogging at different growth stages.

Fig. 2. Effect of 3 days waterlogging 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: Poddng; PD: Pod developing; M: Grain maturing stage; C: Control; non-waterlogging.
Fig. 4. Effect of 3 days waterlogging at different growth stages on the efficiencies of grain and grain protein production of mungbean.

\[
\text{Grain yield} \times 100 \\
\text{Dry weight of plant top} \\
\text{Total nitrogen in grain} \times 100 \\
\text{Total nitrogen in plant top}
\]

EF: Early flowering; F: Flowering; P: Podding; PD: Pod developing; M: Grain maturing stage; C: Control (non-waterlogging).

Both the plant dry weight and total nitrogen showed the lowest amounts in the plants with waterlogging at fully flowering stage, and they gradually increased with the delay of treatment time. The decrease in plant total nitrogen was partly concerned with the depression of symbiotic nitrogen fixing capacity induced directly by the waterlogging treatment as shown in Fig. 3. Another reason for the low plant total nitrogen was considered to be due to the inhibitory effect on nitrogen uptake from soil though this was not quantitatively investigated.

Fig. 4 shows the efficiencies of grain and grain protein production\(^{16,17}\) calculated from the results in Figure 2. Both efficiencies showed a similar tendency to that of grain yield, in which the tendencies of the plants with waterlogging at fully flowering and podding stages were particularly low. The slight decrease in efficiencies in waterlogged plants at early stage was considered to bring about comparatively higher grain and grain nitrogen yields of mungbean.

It was clarified from these results that similar to the responses of severe wilting\(^{17}\), waterlogging at fully flowering and podding stages reduced grain yield and production efficiencies of mungbean, and it should be paid much attention on the irrigation management for the cultivation of mungbean, particularly at the above noted stages.

Summary

Waterlogging treatment was carried out at different growth stages of mungbean to investigate the effect on the growth, grain productivity, and also nitrogen nutrition of mungbean by using soil pot culture method. The results obtained were as follows:

1) The waterlogging treatment at all growth stages of mungbean brought about same inhibition of plant growth, grain yield and a decrease of plant total nitrogen. Particularly, the inhibitory effects were markedly high when waterlogging occurred at fully flowering and podding stages.

2) The decrease of grain yield in the plants noted above was mainly due to the decrease of pod number and to the decrease of grain weight in these pods.

3) The efficiencies of grain and grain protein production of mungbean were also lowest when waterlogging was treated at the above stages.

4) Waterlogging brought about the disappearance of leghaemoglobin in root nodules and the inhibition of nitrogen fixing activity by mungbean nodules. This activity was gradually decreased and was almost zero within three days of waterlogging.

References

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* In Japanese with English summary