Effect of tillage and moisture levels on growth, yield and nodulation of common bean (*Phaseolus vulgaris*) and mungbean (*Phaseolus radiatus*) in the dry season

U.R. SANGÄKKARA
Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka 20400

Received: July 2002

ABSTRACT

A field experiment was conducted at the Experimental farm of the University of Peradeniya, Sri Lanka, over 2 dry seasons (May–August 1999 and 2000) to evaluate the impact of tillage and soil moisture on growth, yield and nodulation of common bean (*Phaseolus vulgaris* L.) and mungbean (*Phaseolus radiatus* L). The legumes were grown in tilled or compacted soils, under rainfed or irrigated conditions, which corresponded to low or high soil-moisture regimes. Germination of the small-seeded mungbean was reduced by soil compaction and low moisture. Crop growth of mungbean was also reduced to a greater extent by soil compaction and moisture stress. In contrast, the adverse impact of soil compaction and moisture stress was greater on pod yields of common bean than on seed yields of mungbean. Tillage promoted root branching to a greater extent than root dry weights of both species, especially in the low soil-moisture regime. Nodulation was reduced to a greater extent by soil-moisture stress especially in common bean, the poor nodulating species.

Key words: Food, Legumes, Dry season, Growth, Yield, Nodulation, Tillage, Soil moisture

Food legumes are a vital component in Asian cropping systems owing to their ability to provide significant quantities of proteins to the vegetarian diet (FAO, 1999). Furthermore, the biological process of nitrogen (N$_2$) fixation is considered a key factor in maintaining productivity and sustainability in small holder tropical agricultural systems, where soils are generally deficient in N (Hungria and Vargas, 2002). Hence legumes are grown in a wide of environments in Asia to provide food and fodder, and are subjected to many types of environmental stresses which affect growth, yield and biological N$_2$ fixation.

Soil moisture is identified as the principal stress factor in tropical agriculture (Turner, 2001), and growth and N$_2$ fixation are affected by this phenomenon (Serraj *et al.*, 1999). The different soil types in the tropics also affect growth of crops, and Buttery *et al.* (1999) reported that soil compaction restricted growth and nodulation of legumes under temperate climatic conditions. Thus a field study was carried out to ascertain the impact of soil compaction and moisture on growth, yield and nodulation of common bean and mungbean over 2 dry seasons, where crops were subjected to drought stress.

MATERIALS AND METHODS

An experiment was carried out during the dry seasons of 1999 and 2000 (April – August) at the Experimental Station of the University of Peradeniya (8° N, 8° E, 421 m above sea-level). The rainfall received during the 2 seasons, lasting from late April to early August was 438 and 319 mm respectively. The mean pan evaporation in the 2 seasons were 598 and 645 mm. As the rainfall was sporadic, the rainfed crops were subjected to moisture stress. The mean temperatures of the 2 seasons were 32.6°C and 33.1°C, respectively, while the humidity was 64.6% ± 1.45%. The mean day-length ranged between 11 and 12 hrs.

The soil of the site was an Ultisol (Rhododult) (Panabokke, 1996), with pH (1.25 H$_2$O) of 6.34 ± 0.42. The texture was a clay loam, with a bulk density of the undisturbed soil, being 1.65 ± 0.51 g/cm$^3$. Hence the soil was compacted during the dry season.

Treatments involving soil compaction and soil moisture regimes were imposed to each crop planted in the same plot in both seasons. The soil was either tilled manually to obtain a mean bulk density of 1.34 ± 0.24 g/cm$^3$ at planting or left untilled. The 2 moisture regimes were either rainfed or irrigated manually at 3-day intervals to maintain 70–80% moisture availability, which was checked gravimetrically every 3 days using core samples from plots. In contrast, the mean soil moisture of the rainfed plots varied between 20 and 30% of available moisture throughout the growing season, expect during rains when the soil-mois-
ture regime reached 80–90% of field capacity. However, this moisture regime did not last for more than 2–3 days due to the high evaporation losses, subjecting the crops to moisture stress. Thus each crop was subjected to 4 treatments laid out in a randomized block design with 4 replications.

With the onset of the first season in late April 1999, plots of 3 m × 4 m demarcated. The weeds were removed and the plots to be tilled were prepared manually. Uniform seeds of the 2 species were planted at a spacing of 10 cm × 20 cm. In the untilled plots, sowing was done using an iron rod without disturbing the soil.

A basal fertilizer application equivalent to 20 kg N, 40 kg P and 45 kg K/ha was applied at planting followed by a top-dressing of 20 kg N and 30 kg K/ha at 30 days after planting. Weeding was done manually on 2 occasions and pesticides were not applied. The plots to be irrigated were supplied with water manually (60 litres/plot) at 3-day intervals to saturate the soil (indicating field capacity) at the end of each irrigation.

After harvesting the first crops, the plots were left fallow until the next season. The same procedure was adopted in the second year and the treatment were allocated to the plots.

Germination of each species was recorded within fixed quadrats, from planting until 14 days. From 10 days after germination until pod set, 3 plants were carefully uprooted from each plot at 5-day intervals, and shoots and roots were dried at 80°C for 48 hr and weighed. These data were used to calculate crop growth rates of each species in each treatment.

At flower initiation, 5 plants were carefully removed from each plot, roots were washed and primary and secondary root branches were counted. Thereafter the nodules/plant were also counted and a sub-sample of nodules checked for effectiveness based on visual observations of the interior tissues (pink). Thereafter, the roots were dried at 80°C for 48 hr and weighed.

At pod maturity of beans and seed maturity of mungbean, yields were determined from an area of 1.25 m² in each plot.

Due to the similarity of the response of the 2 species to the adopted treatments in the 2 seasons, the data were pooled for analysis. A general linear model was used for the analysis of data to determine the significance of observed differences and that of interactions.

RESULTS AND DISCUSSION

Germination

Soil compaction and moisture levels had a significant effect on germination of common bean and mungbean (Table 1). Mean germination of common bean, having large seed (100-seed weight, 230.1 g) was lower than mungbean, having smaller seed (100-seed weight, 47.4 g). Tillage reduced compaction and had a greater positive impact on mean germination of the small seed mungbean. This indicated that a large seed crop could overcome problems of soil compaction due to inherent vigour and stored reserves, which produced a more robust seedling to emerge through compacted soil.

Lack of adequate soil moisture reduced germination in the compacted soil by 28% and 23% in common bean and mungbean respectively. The reduction in germination due to low soil moisture in the tilled soil was similar in both species (16–17%), thereby implying that soil moisture is critical in compacted soils to ensure good germination of these legumes.

Crop growth

Tillage increased crop-growth rate of both species by 33% and 36% when compared that of plants in non-tilled plots (Table 1), highlighting the importance of reducing compaction to ensure optimal growth of plants (Buttery et al., 1999). In contrast, the effect of soil moisture on crop growth was greater in mungbean than in common bean. The impact of low soil moisture in mungbean was greater in compacted (47%) when compared to the tilled soil (42%). This illustrated the requirement of more conducive environment for mungbean to growth successfully.

Root growth

Soil compaction and moisture levels affected root growth of crops significantly. The root branches were lower in common bean than in mungbean (Table 1). The reduction in soil compaction increased root branching of common bean by 62% at flowering stage. In mungbean, root branches were increased by 53% due to tillage. However, the impact of tillage on root weights was marginal in both species. This indicates that the response of both species to compaction is variable for numbers of root branches and dry-matter partitioning. The compacted soil seemed to induce the production of a lower number of heavier roots, while tillage promoted greater branching.

Soil moisture had a greater effect on root branching of common bean than tillage (Table 2). In the compacted soil, low soil moisture reduced root branches by 57% when compared to well-watered conditions. The effect of soil moisture on root weight was lower (40%) in the compacted soil. This clearly indicated that soil moisture has a greater influence on root branching than on root dry weights in compacted soils. In the tilled soils, low soil moisture increased root branches by 6–9% over that of observed with high soil moisture. The low soil moisture re-
gime increased root dry weights marginally by 2% in the flowering stage, over that of plants grown under a high moisture regime. This implied that the impact of soil moisture on common bean root growth is less prominent in the tilled soil when compared to the compacted soil. Furthermore, in a tilled soil low soil moisture increased root length to a greater extent than dry weight to extract available soil moisture.

In mungbean, the response of root lengths to soil moisture in tilled and compacted conditions were similar to that of common bean, but of a lower magnitude. The reductions in root branching due to low soil moisture in the compacted soil was 38% when compared to that observed under high soil moisture. The corresponding reductions in root dry weights when compared to that of well-watered conditions was 32%. In the tilled soil, a low soil-moisture regime increased root branching by 14% when compared with well-watered conditions, while the increments in root dry weights was 13%.

The results highlight that root branching in both species is more sensitive to low soil moisture. In a compacted soil, both species tend to reduce branching to a greater extent under low soil moisture, but generally produce heavier roots, as seen by the lower decline in root dry weights. This could be attributed to the resistance offered by the compacted soil to the development of more roots. In the tilled soil, low moisture induces greater branching to facilitate greater absorption of water. The roots are also heavier, thus facilitating better soil moisture uptake due to lower resistance offered by the soil for root development.

Generally, the magnitude of the responses of root growth to soil compaction and moisture was greater in common bean, a drought-susceptible species when compared to mungbean.

**Nodulation**

Soil compaction reduced the nodulation of both species (Table 1). The impact of compaction was significantly greater in common bean, a low-nodulating legume, and tillage increased nodulation by 100%. In mungbean, the increment in nodulation due to tillage was lower (18%). However, the impact of compaction on effective nodules was less prominent, thus indicating the ability of the plants to maintain nitrogen fixation although nodule numbers are reduced.

Soil moisture affected nodulation significantly in both species, as reported for other legumes (Serraj et al., 1999). In common bean, the low soil-moisture regime in

### Table 1. Establishment, growth, yields and nodulation of field grown common bean and mungbean as affected by soil compaction and moisture

<table>
<thead>
<tr>
<th>Soil compaction</th>
<th>Moisture</th>
<th>Germination (%)</th>
<th>Crop growth rate (g/m²/day)*</th>
<th>At flowering</th>
<th>Pod or seed yield* (g/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Root branches</td>
<td>Root dry weight (g)</td>
<td>Nodules/ plant</td>
</tr>
<tr>
<td>Compacted</td>
<td>High</td>
<td>75</td>
<td>4.25</td>
<td>49</td>
<td>47.6</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>54</td>
<td>2.84</td>
<td>21</td>
<td>28.0</td>
</tr>
<tr>
<td>Tilled</td>
<td>High</td>
<td>79</td>
<td>5.95</td>
<td>54</td>
<td>37.4</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>65</td>
<td>3.74</td>
<td>59</td>
<td>38.2</td>
</tr>
<tr>
<td>LSD (P=0.05)</td>
<td></td>
<td></td>
<td>4.15</td>
<td>0.84</td>
<td>5.9</td>
</tr>
<tr>
<td>Compaction</td>
<td></td>
<td></td>
<td>8.40</td>
<td>0.45</td>
<td>3.6</td>
</tr>
<tr>
<td>Moisture</td>
<td></td>
<td></td>
<td>2.15</td>
<td>0.05</td>
<td>4.4</td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
<td>8.4</td>
<td>0.2</td>
<td>1.7</td>
</tr>
<tr>
<td>CD</td>
<td></td>
<td></td>
<td>81</td>
<td>3.86</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>62</td>
<td>1.98</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>88</td>
<td>4.99</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>74</td>
<td>2.81</td>
<td>71</td>
</tr>
<tr>
<td>LSD (P=0.05)</td>
<td></td>
<td></td>
<td>5.10</td>
<td>0.49</td>
<td>4.8</td>
</tr>
<tr>
<td>Compaction</td>
<td></td>
<td></td>
<td>1.89</td>
<td>0.62</td>
<td>2.9</td>
</tr>
<tr>
<td>Moisture</td>
<td></td>
<td></td>
<td>0.53</td>
<td>0.07</td>
<td>4.1</td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
<td>9.6</td>
<td>0.7</td>
<td>8.4</td>
</tr>
</tbody>
</table>

Soil moisture levels: High, irrigated conditions; Low, rainfed conditions

*Crop growth rate is based on shoot biomass from 2 weeks after germination to pod set; number in parentheses indicates percentage effective nodules based on colour (pink internal tissue)

*Pod yield of common bean and seed yield of mungbean
the compacted soil reduced nodule numbers by 52%. The reduction in nodulation in the tilled soil due to low soil moisture was significantly lower (26%).

In mungbean, the lower moisture regime in the compacted soil reduced nodules by 17%, while the reductions in the tilled soil due to low moisture was 16%. This showed that nodulation is reduced by soil compaction and moisture stress and the impact is greater is common bean. Hence tillage and adequate soil moisture seem to be of greater importance to this species than in the more prolific nodulating mungbean. An overall comparison between the response of roots and nodulation to soil compaction and moisture stress in the 2 species does not indicate a clear relationship. Although root development was enhanced in the tilled soil when subjected to moisture stress, nodulation declined.

Seed yield

The mean seed yield of mungbean was increased by 66% due to tillage, compacted to a 59% increase in pod yield of common bean (Table 1). However, the impact of soil-moisture availability on yield of common bean was similar in both compacted and tilled soil. The reduction in yield of mungbean due to low soil moisture was significantly greater in the tilled soil (33%) than in the compacted soil (18%). This indicates that soil moisture is more critical for mungbean grown in a tilled soil. However, this could also be due to the greater yields obtained with adequate soil moisture in a tilled soil. The pod yield of common bean was more vulnerable to soil-moisture stress in the 2 soil types, reflecting the greater vulnerability of common bean to soil-moisture stress than a more drought-hardy species such as mungbean.

REFERENCES


