ORIGINAL ARTICLE

Effects of soaking seed and fertilizer placement on growth and yield of soybean grown after rice in the post-monsoon season in Khon Kaen Province

Anan Polthanee[1] and Vidhaya Tre-loges[2]

Abstract

Polthanee, A.[1] and Tre-loges, V.[2]
Effects of soaking seed and fertilizer placement on growth and yield of soybean grown after rice in the post-monsoon season in Khon Kaen Province
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The experiment was conducted in a farmer's field in Ban Fang District, Khon Kaen Province in 1999-2000. The objective of this study was to investigate the effect of soaking seed in water or not soaking before seeding, and fertilizer placement (surface broadcast at seeding, banding below the seed at seeding and banding beside the plant row 10 days after seeding) on growth and yield of soybean grown after rice in the post-monsoon season. The results showed that soaking seed before seeding had no significant effect on leaf area per plant, total top dry weight, root length density, pod number per plant, seed number per pod, 100-seed weight and seed yield of soybean. However, soybean growth, yield components and seed yields tended to be higher with no soaking. Therefore, soaking seeds in water before seeding had no advantage over no soaking in terms of early emergence and early maturity before the plant was subjected to water stress at grain filling phase. Fertilizer placement had a significant effect on growth and yield of soybean. Banding application gave higher leaf area per plant, total top dry weight, root length density, pod number per plant and seed yield than those of broadcast application. Banding generally increased leaf N, P and K concentration. There was no significant difference in seed yield between belowband and sideband application. Belowband application tended to produce higher seed yield than that of sideband application. Belowband application at planting

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saved labour as compared with sideband application. To obtain a satisfactory yield of soybean grown following rice in the post-monsoon season during the rainless period, however, shallow depth of groundwater table to provide upward movement of water to the root zone should be considered.

Key words : soaking seed, fertilizer placement, soybean, sequential cropping

บทคัดย่อ

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ผลของการแช่เมล็ดและวิธีการใส่ปุ๋ยที่มีต่อการเจริญเติบโตและผลผลิตของถั่วเหลืองเมื่อปลูกหลังข้าว ที่จังหวัดขอนแก่น

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ทำการทดลองในแปลงนาเกษตรกร อ.บ้านฝาง จ.ขอนแก่น ในปี 2543-2544 มีวัตถุประสงค์ เพื่อศึกษาผลของการแช่เมล็ดในน้ำและไม่มีการแช่เมล็ดในน้ำก่อนปลูก รวมทั้งศึกษาวิธีการใส่ปุ๋ย (หว่านปุ๋ยบนผิวดินพร้อมปลูก โรยปุ๋ยลงในร่องลึกประมาณ 5 ซม. ใต้เมล็ดพืชพร้อมปลูก และโรยปุ๋ยลงในร่องลึกประมาณ 5 ซม. ห่างจากแถวพืชประมาณ 10 ซม. หลังปลูก 10 วัน) ที่มีต่อการเจริญเติบโตและผลผลิตของถั่วเหลืองเมื่อปลูกหลังเก็บเกี่ยวข้าว ผลการศึกษาพบว่า การแช่เมล็ดในน้ำก่อนปลูก ไม่มีผลทำให้พื้นที่ใบต่อต้น น้ำหนักแห้งรวม ความหนาแน่นราก จำนวนฝักต่อต้น จำนวนเมล็ดต่อฝัก น้ำหนัก 100 เมล็ด และผลผลิตเมล็ด มีความแตกต่างกันทางสถิติ อย่างไรก็ตาม มีแนวโน้มว่าการปลูกถั่วเหลืองโดยไม่มีการแช่เมล็ดในน้ำก่อนปลูกทำให้องค์ประกอบผลผลิตและผลผลิตเมล็ดสูงกว่าการปลูกถั่วเหลืองโดยมีการแช่เมล็ดในน้ำก่อนปลูกเพียงเล็กน้อย ดังนั้น การแช่เมล็ดในน้ำก่อนปลูก เพื่อที่จะให้เมล็ดถั่วเหลืองงอกได้เร็วและเก็บเกี่ยวได้เร็วก่อนที่พืชจะประสบกับสภาวะขาดน้ำในระยะสะสมอาหารในเมล็ดจึงไม่ประสบผลสำเร็จ ส่วนวิธีการใส่ปุ๋ยมีผลต่อการเจริญเติบโตและผลผลิตของถั่วเหลือง การใส่ปุ๋ยลงในร่องใต้เมล็ดพร้อมปลูก และการใส่ปุ๋ยโดยโรยลงไปในร่องข้างแถวพืชหลังปลูก 10 วัน ให้พื้นที่ใบต่อต้น น้ำหนักแห้งรวม ความหนาแน่นราก จำนวนฝักต่อต้น และผลผลิตเมล็ดมากกว่าวิธีการใส่ปุ๋ยโดยการหว่านบนผิวดินพร้อมปลูก อย่างไรก็ตาม ผลผลิตที่ได้ไม่มีความแตกต่างกันทางสถิติระหว่างการใส่ปุ๋ยลงไปในร่องใต้เมล็ดพร้อมปลูก และการใส่ปุ๋ยแบบโรยลงไปในร่องข้างแถวพืชหลังปลูก 10 วัน แต่มีแนวโน้มว่าการปลูกถั่วเหลืองโดยมีการใส่ปุ๋ยแบบโรยลงไปในร่องใต้เมล็ดพร้อมปลูก ให้ผลผลิตสูงกว่าวิธีการใส่ปุ๋ยแบบโรยลงไปในร่องข้างแถวพืชหลังปลูก 10 วัน การปลูกถั่วเหลืองโดยมีการใส่ปุ๋ยแบบโรยลงไปในร่องใต้เมล็ดพร้อมปลูก ใช้แรงงานน้อยกว่าการใส่ปุ๋ยโดยวิธีเปิดร่องข้างแถวพืชแล้วโรยปุ๋ยหลังปลูก 10 วัน อย่างไรก็ตาม การปลูกถั่วเหลืองหลังข้าวที่จะให้ผลผลิตได้เป็นที่น่าพอใจ สภาพพื้นที่ปลูกควรจะมีระดับน้ำใต้ดินตื้น

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Food production in many rainfed, rice cultivation areas of South and Southeast Asia could be increased through greater production of dryland crops grown after rice during the post-monsoon dry season. The productivity of these crops depends largely on successful crop establishment and the availability of soil water (Zandstra, 1982). In general, the crops produce poor yield due to water stress during the seed-filling phase (Polthanee, 1998)

Pre-germination of peanut seeds by soaking in water before planting results in a minimized lag period between sowing and seedling establishment (Polthanee, 1991). The early seed emergence

leads to an early use of soil moisture, and crop maturity prior to experiencing water stress.

Under drought conditions, it is generally accepted that it is best to place the fertilizer in the zone of the soil that retains water for a greater part of the season (Tisdale and Nelson, 1975). Deep placement of N and K fertilizer for sorghum gives greater uptake under dry conditions (Eck and Fanning, 1961). In contrast, depth of placement has no effect on uptake of phosphorus in sorghum under dry conditions and uptake was quite low (Eck and Fanning, 1961).

Banding fertilizer to the side and below the seed row has been shown to increase nutrient uptake and yield of wheat (Cochran *et al*., 1990) and barley (Cochran and Schlentner, 1992). Soybean yield was higher with banded fertilizer P when compared with broadcast applications (Bullen *et al*., 1983). In contrast, Lutz and Jones (1974) have shown that broadcast application of P improves soybean yields when compared to deep placement. The objectives of this study were to evaluate the effects of soaking seed in water and fertilizer placement on growth and yield of soybean grown after rice in the post-monsoon season in Khon Kaen Province.

Materials and Methods

The experiment was conducted in a farmer's field in Ban Kok Yai, Ban Fang district, Khon Kaen province in the period of December 2000 to March 2001. The soil was a Typic Hapludalf of the order Alfisol. The texture of the soil is sandy loam with a pH of 4.9, organic matter content of 0.95%, available P of 45.8 ppm and available K of 14.0 ppm.

A split plot design was used with seed treated (soaking seed in water for 2 hours before seeding and no-soaking seed) as main-plots factor and fertilizer placement as sub-plots factor (surface broadcast at seeding, band 5 cm below the seed row at seeding and band 5 cm beside the plant row 10 cm away from plant 10 days after seeding). The whole experimental area was ploughed twice and harrowed prior to planting. Soybean seeds of variety "KKU Early No. 5" were inoculated with rhizobium before seeding. Three to four seeds were dropped in the furrows made by planet junior (hand tool) and covered with soil with plant spacing of 50×20 cm.

A chemical fertilizer 12-24-12 (N, P_2O_5, K_2O) at rate of 156 kg ha^{-1} was used in the experiment. The crops were thinned to 2 plants per hill at 10 days after planting (DAP). Hand weeding was done once at 30 DAP. Monocrotophos was sprayed to control pod borer at 60 and 75 DAP.

Rainfall and air temperature were recorded during the growing season. Observation wells of perforated PVC tubes were installed at 2 m depth. Water table depth was measured at 7 DAP and weekly intervals thereafter until harvest. Soil moisture contents of samples from 0-15, 15-30 and 30-45 were determined by the gravimetric procedure at 7 DAP and at weekly intervals thereafter until harvest.

Five plants from each plot were taken for total top dry weight and leaf area measurements. Leaf area was measured at 15, 35 and 65 DAP using a leaf area meter (Model No. ACC-400, Hayashi Denko Co. Ltd., Japan). Root samples were taken at physiological maturity using soil core at 0-10, 10-20 and 20-30 cm soil depths. Two samples of root were taken, one from the area where the main root mass was located and a second from between soybean rows of each plot. Root growth was estimated by counting the number of intersections between roots and the horizontal/vertical line on a 1×1 cm square grid. The root length density was calculated according to the method outlined by Tennant (1975). Soybean seed yields and 100-seed weight were determined from 3×4 m harvested area of each plot. The number of pods per plant and seeds per pod were determined from 10 plants subsamples collected from randomly plants. Soybean leaves were taken randomly outside the harvested area at 30 and 65 DAP for N analysis. The data were analyzed using analysis of variance procedures and LSD was used to compare treatment means when F-test was significant.

Results

Rainfall and water table depth

In the present study, rainfall contribution was minimal. The crops received 20 mm of rainfall once at day 50 after planting during the growing period. Therefore, the water available to the crop was supplied mainly from upward movement of water from the shallow water table depth and from residual soil moisture on the soil profile. The measured water table depths ranged from 62 to 87 cm from soil surface during the growing period (Figure 1).

Soil moisture content and temperature

Soil moisture content at 0-15, 15-30 and 30-45 cm depth were mostly maintained in the available ranges (between field capacity and permanent wilting point level) during the entire growing period (Figures 2, 3 and 4). The results

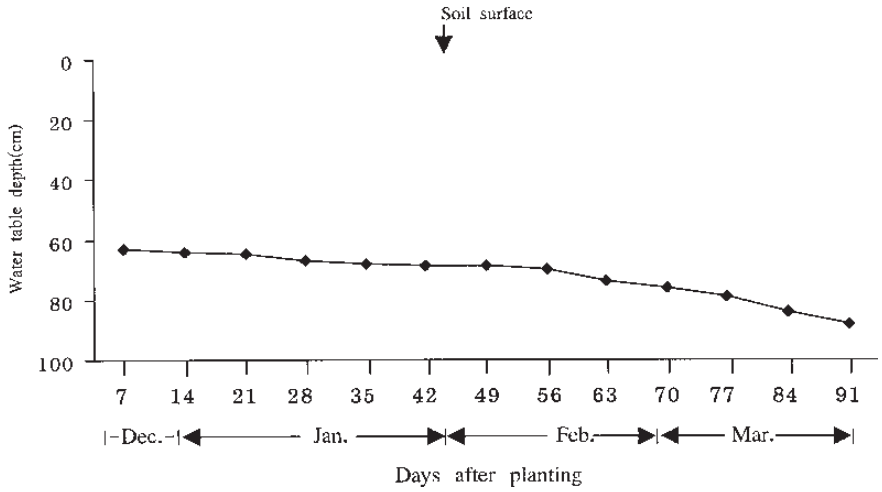

Figure 1. Average water table depth fluctuation during the experimental period.

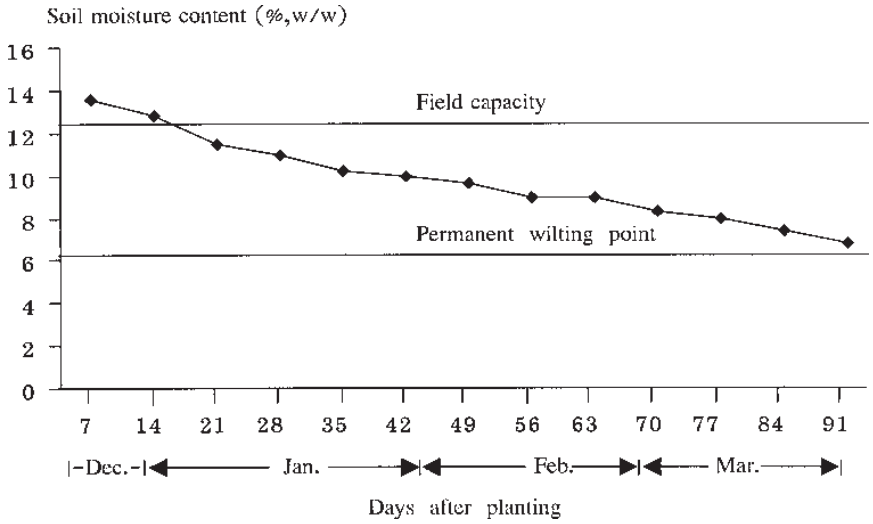

Figure 2. Average soil moisture content at 0-15 cm depth during the experimental period.

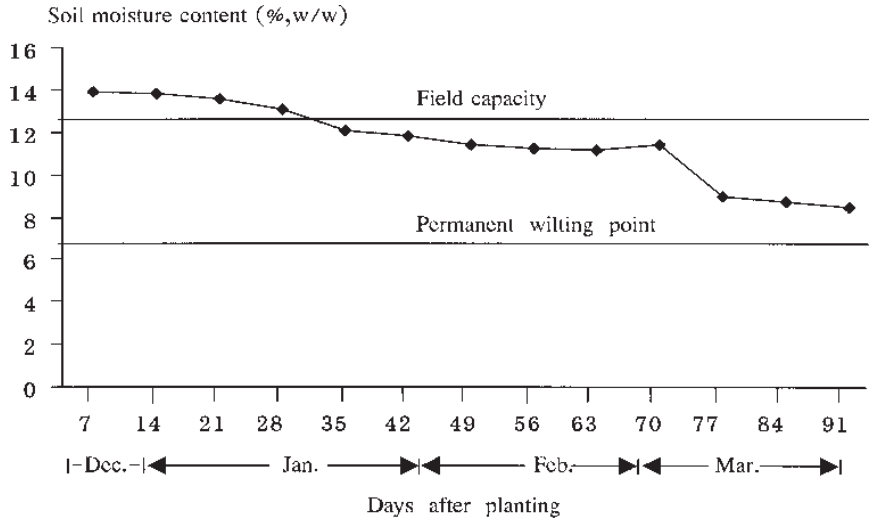

Figure 3. Average soil moisture content at 15-30 cm depth during the experimental period.

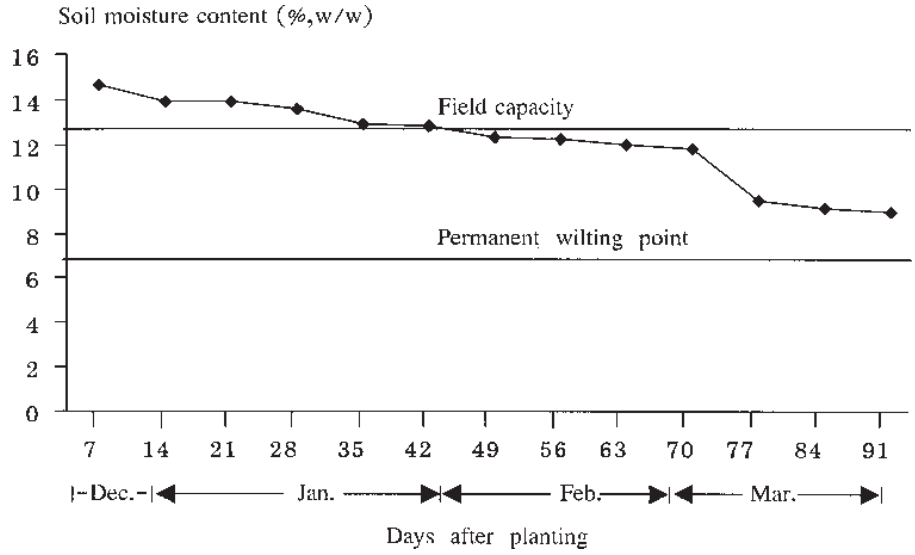

Figure 4. Average soil moisture content at 30-45 cm depth during the experimental period.

indicated that the plants received adequate soil moisture throughout the growing period.

In the present study, the maximum and minimum air temperature ranged from 29.3 - 33.4 ºC and 15.3 to 20.5 ºC, respectively during the growing period (Figure 5). It is noticed that maximum temperature was mostly above 30 ºC during the growing period.

Germination

Seed soaking for 2 hours before seeding did not have a significant effect on days to emergence and germination percentage as compared to no-soaked seed (data not shown). However, the soybean stand was slightly decreased when seeds were soaked before seeding. In the present study, low vigor seedlings were observed with soaking seeds.

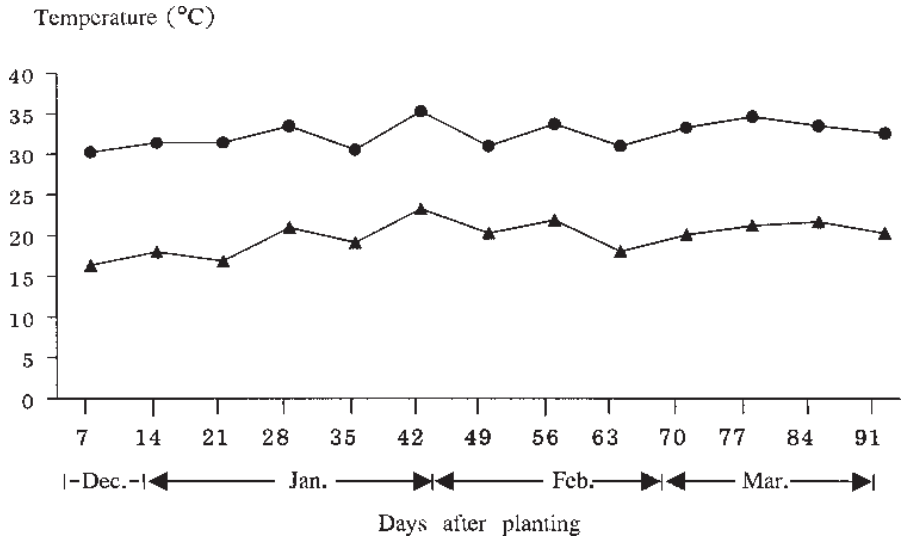

Figure 5. Weekly mean maximum (▲——▲) and minimum (●——●) air temperature during the experimental period.

Table 1. Nitrogen (N) and phosphorus (P) concentration in leaves of soybean grown after rice, at 30 and 65 days after planting (DAP), as influenced by soaking seed and fertilizer placement

Treatment	N (g/kg)[1/]		P (g/kg)[1/]	
	30 DAP	65 DAP	30 DAP	65 DAP
Seed treatment (ST)				
Soaking (S)	36.6	26.2	3.0	3.3
No-soaking (NS)	36.1	28.2	3.0	3.0
F-test	NS	NS	NS	NS
Fertilizer placement (FP)				
Broadcast (B)	25.1b	25.0b	2.8b	2.9b
Belowband (BB)	37.3a	29.9a	3.2a	3.3a
Sideband (SB)	36.7b	26.7a	3.0a	3.2a
F-test	**	*	*	*

*** = Significant at P<0.05, ** = Significant at P < 0.01, NS = Not significant**
[1/] = Mean followed by the same letter at the same column was not significantly difference by LSD.

Nutrient concentration

Soybean seeds with and without soaking before seeding had no effect on N concentration in soybean leaf, but fertilizer placement had a significant effect on N concentration in soybean leaf at 30 and 65 DAP (Table 1). Belowband application gave the maximum N concentration of soybean leaf at 30 and 65 DAP. There was no interaction effect of seed treatment and fertilizer placement in this experiment.

Irrespective of P, soybean seeds with and without soaking in water before seeding had no

significant effect on P concentration of soybean leaf, but fertilizer placement had an influence on P concentration of soybean leaf at 30 and 65 DAP (Table 1). The maximum P concentration of soybean leaf was obtained with belowband and sideband application. There was no interaction effect of seed treatment and fertilizer placement in the present study.

Considering K, seed treatment and fertilizer placement had a significant effect on K concentration in soybean leaf at 30 DAP (Table 2). Soybean seed without soaking before seeding gave the highest K concentration in soybean leaf. The maximum K concentration was obtained with banding applications (belowband and sideband). However, there was no significant difference between seed treatments and fertilizer placements on K concentration of soybean leaf at 65 DAP (Table 2). In the present experiment, there was no interaction effect of seed treatment and fertilizer placement on K concentration of soybean leaf.

Leaf area per plant

Soybean seed with and without soaking before seeding had no significant effect on leaf area per plant at 15, 35 and 64 DAP, but fertilizer placement affected on leaf area per plant at 65 DAP (Table 3). The highest leaf area per plant was obtained with belowband application. There was no interaction effect between seed treatment and fertilizer placement on leaf area per plant of soybean at 15, 35 and 65 DAP.

Total top dry weight

Soaking or not soaking soybean seed in water before seeding had no significant effect on

Table 2. Potassium (K) concentration in leaves of soybean grown after rice, at 30 and 65 days after planting (DAP) as influenced by soaking seed and fertilizer placement

Treatment	K (g/kg)[1/]	
	30 DAP	65 DAP
Seed treatment (ST)		
Soaking (S)	7.0B	6.6
No-soaking (NS)	7.9A	6.4
F-test	**	NS
Fertilizer placement (FP)		
Broadcast (B)	7.0b	6.1
Belowband (BB)	7.7a	6.8
Sideband (SB)	7.7a	6.6
F-test	*	NS

*** = Significant at P <0.05, ** = Significant at P <0.01,**
NS = Not significant
[1/] = Mean followed by the same letter at the same column was not significantly difference by LSD.

Table 3. Leaf area (cm^2/plant) of soybean grown after rice at 15, 35 and 65 days after planting (DAP) as influenced by soaking seed and fertilizer placement

Treatment	15 DAP	35 DAP	65 DAP[1/]
Seed treatment (ST)			
Soaking (S)	83.6	341.4	980.4
No-soaking (NS)	83.7	363.4	1146.5
F-test	NS	NS	NS
Fertilizer placement (FP)			
Broadcast (B)	83.7	317.1	867.9b
Belowband (BB)	89.1	378.3	1139.0a
Sideband (SB)	78.2	361.8	1133.4a
F-test	NS	NS	*

*** = Significant at P <0.05, NS = Not significant**
[1/] = Mean followed by the same letter at the same column was not significantly difference by LSD.

total top dry weight at 15, 35 and 65 DAP, but fertilizer placement affected the total top dry weight at 35 and 65 DAP (Table 4). The maximum total top dry weight was obtained when soybean received fertilizer with belowband application. There was an interaction effect between seed treatment and fertilizer placement on total top dry weight at 35 DAP. Soybean seeds soaked in water before seeding with belowband fertilizer placement gave greater total top dry weight. Under sideband and below condition, the total top dry weight more decreased but the opposite results was found in the belowband application as shown in Figure 6.

Root length density

Soybean seed with and without soaking in water before seeding had no significant effect on root length density (RLD) at 0-10, 10-20 and 20-

Table 4. Total top dry weight (g/plant) of soybean grown after rice, at 15, 35 and 65 days after planting (DAP) as influenced by soaking seed and fertilizer placement

Treatment	15 DAP	35 DAP[1/]	65 DAP[1/]
Seed treatment (ST)			
Soaking (S)	0.52	4.7	11.8
No-soaking (NS)	0.54	5.0	13.5
F-test	NS	NS	NS
Fertilizer placement (FP)			
Broadcast (B)	0.53	3.7b	10.3b
Belowband (BB)	0.57	5.3a	13.5a
Sideband (SB)	0.50	5.0a	13.3a
F-test	NS	*	*

*** = Significant at P <0.05, NS = Not significant**
[1/] = Mean followed by the same letter at the same column was not significantly difference by LSD.

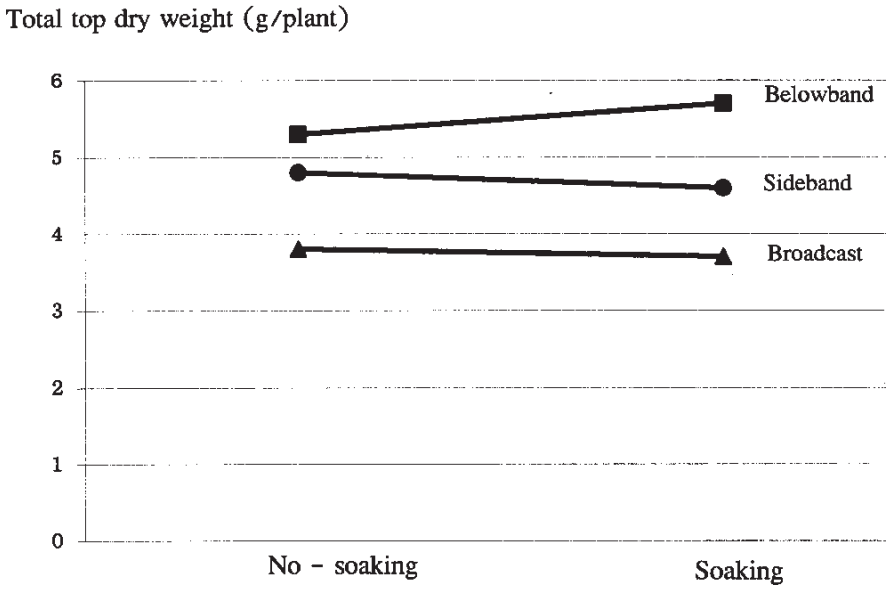

Figure 6. Total top dry weight of soybean as influenced by soaking seed and fertilizer placement.

30 soil depth, but RLD was significantly affected by fertilizer placement (Table 5). The maximum RLD was attained when soybean received fertilizer with belowband application. There was no interaction effect between seed treatment and fertilizer placement on RLD (Table 5).

Yield components

Pod number per plant, seed number per pod and 100-seed weight were not affected by seed treatment (Table 6). Fertilizer placement had no significant effect on seed number per pod and 100-seed weight, but affected pod number per plant (Table 6). The highest pod number per plant was obtained when soybean received fertilizer with belowband application. There was no interaction effect between seed treatment and fertilizer placement on yield components.

Table 5. Root length density (cm/cm^3) of soybean grown after rice at harvest as influenced by soaking seed and fertilizer placement

Treatment	Soil depth (cm)[1/]		
	0-10	10-20	20-30
Seed treatment (ST)			
Soaking (S)	0.045	0.026	0.007
No-soaking (NS)	0.048	0.029	0.007
F-test	NS	NS	NS
Fertilizer placement (FP)			
Broadcast (B)	0.037b	0.019b	0.006b
Belowband (BB)	0.055a	0.035a	0.010a
Sideband (SB)	0.048a	0.030a	0.007b
F-test	**	**	*

*** = Significant at P <0.05 , ** = Significant at P <0.01 , NS = Not significant**
[1/] = Mean followed by the same letter at the same column was not significantly difference by LSD.

Table 6. Seed yield, pod number per plant, seed number per pod and 100 seed weight of soybean as influenced by soaking seed and fertilizer placement

Treatment	Seed yield[1/] (kg/ha)	Pods per[1/] plant (no)	Seeds per pod (no)	100-seed weight (g)
Seed treatment (ST)				
Soaking (S)	1184.7	21.9	2.3	12.9
No-soaking (NS)	1245.0	22.4	2.4	12.6
F-test	NS	NS	NS	NS
Fertilizer placement (FP)				
Broadcast (B)	1016.1b	19.5b	2.3	12.7
Belowband (BB)	1346.3a	24.4a	2.4	12.9
Sideband (SB)	1282.3a	22.7a	2.4	12.8
F-test	**	**	NS	NS

**** = Significant at P < 0.01, NS = Not significant**
[1/] = Mean followed by the same letter at the same column was not significantly difference by LSD.

Seed yield

Soaking or not soaking soybean seeds in water before seeding had no significant effect on seed yield of soybean, but seed yield was affected by fertilizer placement (Table 6). Belowband application gave the highest seed yield of soybean. However, there was no significant difference of soybean seed yield between belowband (1346 kg ha^{-1}) and sideband (1282 kg ha^{-1}) application. Broadcast application gave the lowest seed yield (1016 kg ha^{-1}) of soybean. There was no interaction effect between seed treatment and fertilizer placement on seed yield.

Discussion

Soaking or not soaking soybean seeds in water before seeding had no effect on days to emergence. This was due to soybean seeds having good water absorbing capacities (high seed permeability) (Leopold, 1983; Ragus, 1987). The results indicated that seeds which were soaked in water before seeding had no an advantage over seeds without soaking in terms of early emergence to use residual soil moisture which is limited in the post-monsoon season. Irrespective of germination percentage, seeds soaked in water before seeding had slightly decreased germination percentage. The phenomenon is due in part to soaking injury brought about by the rapid imbibition of water (Woodstock and Tao, 1981; Duke *et al*., 1986). This contrasts with the work done by Syarifuddin (1982) who found that soybean stand was slightly increased when seeds were drilled in between rice row by soaking them about 24 hours before sowing. In the present experiment, low vigor seedlings were also observed when the seeds were soaked in water before seeding. The commonly accepted explanation for this damage is that cell membranes of seeds rupture upon soaking and then the internal contents of the seeds leach out. In effect the resulting low availability of nutrient for the growth and development of the embryo is reflected by poor germination and weak seedling (Ragus, 1987).

Banding application (either belowband or sideband) resulted in better growth and yield of soybean than that of broadcast application. This was due to banding application resulting in greater fertilizer-use efficiency than broadcast application. Banding application results in higher fertilizer concentration for plant growth and leads to greater nutrient concentration in leaf (Tables 1 and 2). Band application increases root length density and enables the roots to reach deeper soil layers in the season (Table 5). Bullen *et al*. (1983) reported that soybean yield increases were higher with banded fertilizer P when compared to broadcast applications. This is contrary to a previous finding in which broadcast application of P improved soybean yields when compared to deep placement (Jones, 1974). According to Buah *et al*. (2000) soybean grain yields for broadcast P and K were better than for band application. Banding urea beneath the soil surface avoids volatile losses of NH_3 (Thorup, 1984). Banding fertilizer to the side and below the seed has been shown to increase N uptake and grain yield of barley (Escala and Larpes, 1986 a) wheat (Cochran *et al*., 1990). Banding K fertilizer in cereals was about 4 times more effective than broadcast (Prummel, 1957).

In the present study, soybean yields had no significant difference between belowband and sideband. However, farmers may apply all of the fertilizer as belowband at planting to save labour. In this study, soybean seemed to produce low seed yield. The 100-seed weight of the yields components was the most affected. This was probably due to maximum air temperature above 30 ^{o}C during the grain filling phase (Figure 5). In addition, the soil moisture content during the period of grain filling phase fell near to the permanent wilting point level (Figure 2). This caused soybean to mature early and resulted in lower 100-seed weight (12.4-13.0 gm). In general, 100-seed weight of soybean in such variety ranges from 14.5-16.6 g.

The possibility of variety selection for high temperature and water stress to maintain high yields should be investigated in future research.

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