ダイズ子実収量と品質に対する緩効性窒素肥料(石灰窒素と被覆尿素),リン,カリウム肥料の深層施肥効果の比較

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Comparison of the Effects of Application of Deep Placement of Slow Release N (Lime Nitrogen and Coated Urea), P and K Fertilizers on Yield and Quality of Soybean (*Glycine max* (L.) Merr.) Seed

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Nitrogen, phosphorus and potassium are three major nutrients, whose availability often become limiting factor to plant growth and crop yield. We have published in our previous reports that a new fertilization method with deep placement of slow release N fertilizers, such as coated urea and lime nitrogen (calcium cyanamide) supplied at 20cm depth from soil surface promoted soybean growth and seed yield. In the present experiment, the effects of deep placement below plants of 100kgN ha^{-1} of N fertilizers, coated urea (CU) and lime nitrogen (LN) in addition to 100kgP_2O_5 ha^{-1} of fused phosphorus (P) and 100kgK_2O ha^{-1} of potassium silicate (K) fertilizers, on growth and seed yield of soybean (*Glycine max* [L] Merr.) plants were examined by comparing with those from control plots in rotated paddy field of Nagaoka. The fertilizers were applied for both the nodulated soybean (cv. Enrei) and the non-nodulated isogenic line (En1282). Different fertilizer combinations were used which includes CU, CU+P, CU+K, CU+P+K, LN, LN+P, LN+K and LN+P+K. The deep placement of the fertilizers, especially LN+P+K, markedly increased the growth of Enrei plants compared to other treatments. The seed yield and visual quality of harvested seeds also showed that LN+P+K enhanced the yield as well as quality of seeds compared to the other treatments. Thus, it is suggested that N fertilization management, like deep placement of slow release N fertilizers in addition to P and K fertilizer, is important for maximum yield and enhancement of seed quality of soybean. As regard to wrinkle seeds, percentage of side wrinkle was higher in CU+K treatment compared with other treatment. The percentage of turtle wrinkle was positively correlated with pealed seeds (R^2=0.707), broken coat (R^2=0.399) and side wrinkle (R^2=0.294), and negatively correlated with the percentage of good seed (R^2=0.587).

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Key words: deep placement, NPK fertilizers, soybean, nitrogen fixation, seed yield and quality

Soybean seeds contain a large amount of nitrogen and the total amount of nitrogen assimilated in plant is highly correlated with soybean seed yield. Sole N_2 fixation is often insufficient to support the vigorous vegetative and reproductive growth of soybean plants. For the maximum yield of soybean, it is necessary to use both nitrogen fixation and absorbed nitrogen from roots (Harper, 1987). It has been known that plants require nitrogen, phosphorus and potassium as three major nutrient elements for good growth and high yield. Nitrogen is essential as protein, nucleic acid and chlorophyll composing elements and it promotes vegetative growth. Phosphorus is a component of nucleic acid and membrane and it promotes root development. Potassium plays to control pH and osmotic pressure in cells as a free cation and it also aids in stress resistance. Therefore, the improvement of N fertilization in terms of chemical and physical forms of fertilizers, as well as the timing and placement of fertilization for soybean, which is compatible with N_2 fixation, is very important (Takahashi *et al.*, 1992). In addition, appropriate application of P, K or organic fertilizers are also important.

It must be noted however that high dose of chemical N fertilization severely depresses nodule formation and N_2 fixation activity. Therefore, the agronomic and biological technology to ensure optimum N_2 fixation through new N fertilization technique is essentially important for increasing and for stable soybean seed production. Takahashi et al. (1991,1992) developed a new fertilization technique for soybean to supplement N during seed filling stage without depressing N_2 fixation by deep placement of slow release N fertilizer, 100 day-type coated urea. Deep placement of coated urea enables the slow release of N in the soil. Although the urea released from coated urea was rapidly hydrolyzed to ammonia, the NH_4^+-N could not be easily nitrified owing to the low activity of nitrification in the deep soil layer of converted rice field (Takahashi and Ohyama, 1999).

Further, we detailed in the previous reports (Tewari *et al.*, 2002, 2003, 2004a) about the enhancement in soybean seed yield by using slow release fertilizers (lime nitrogen as well as coated urea). Lime nitrogen contains about 60% of calcium

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cyanamide ($CaCN_2$) with calcium oxide and carbon. In soil $CaCN_2$ is converted to urea, then to ammonia and carbon dioxide. Dicyandiamide formed during the degradation of $CaCN_2$ is a potent nitrification inhibitor, which retards the nitrification of ammonia. Therefore ammonium produced by $CaCN_2$ degradation persists for a long period of time.

In Japan, soybean seed quality is graded by the percentage of good seeds. In the first, second and third grades, the percentage of good seed weight should exceed 85%, 80% and 75% of the total seed weight. Yield and quality decrease due to diseases of soybean pod and seed occurs regularly. Recently seed with turtle wrinkle and side wrinkle are major problem to decrease the seed quality in Hokuriku area including Niigata prefecture (Tewari *et al.*, 2004b). Many of the insect, pest and fungi, which infect pods and seeds, can remain undetected without causing obvious symptoms. However, if the diseases are expressed, seeds are often discolored, split, or shrunken (Baird *et al.*, 1998). Therefore we have classified the harvested soybean seeds into various categories in order to evaluate the prevalence of diseases, which affect the seed quality and subsequent seed yield of soybean.

In the present study we tried to analyze the effects of the application of different fertilizers, especially controlled release fertilizers such as coated urea and lime nitrogen in addition to phosphorus and potassium fertilizers, on the growth, seed yield and seed quality of soybean plants.

MATERIALS AND METHODS

The experiment was carried out on June 3, 2002 in Niigata Experimental Station, a rotated field that had been converted from a drained paddy field in the previous year. The soil was a Fine-textured Gray Lowland soil (gray type). Chemical properties of the soil were as follows: texture CL; pH(H_2O) 6.8; CEC (cmol(+) kg^{-1}) 25; total Carbon content 1.0%, total N content 0.12 %; C/N, 8.4; amount of mineralized N determined by the incubation of air-dry soil under upland conditions for 4weeks at 30 ℃ (mgN kg^{-1}), 38.

Basal dressing of N (ammonium), phosphorus, potassium and calcium fertilizers (16 kgN ha^{-1}, 60 kgP_2O_5 ha^{-1}, 80 kgK_2O ha^{-1}, 1000 $kgCa(OH)_2$ ha^{-1} respectively) were incorporated into a plow layer about 0-10 cm depth for all the experimental plots. Thereafter, deep placement of 100kgN ha^{-1} of slow release N fertilizers, coated urea (CU) and lime nitrogen (LN) was performed at a 20 cm depth under the planting spot. In addition to N fertilizer, P fertilizer (100kgP_2O_5 ha^{-1} of fused magnesium phosphate) (P) and K fertilizer (100kgK_2O ha^{-1} of potassium silicate) (K) were also incorporated on several plots at 20 cm depth with various combinations as follows: a) Control, b) CU, c) CU+P, d) CU+K, d) CU+P+K, e) LN, f) LN+P, g) LN+K, h) LN+P+K. The deep placement of CU (2.8 g $plant^{-1}$), LN (5.62 g $plant^{-1}$), P (5.62 g $plant^{-1}$) and K (5.62 g $plant^{-1}$) was carried out by digging holes (20cm depth) in field and applying the fertilizers just under the seed placement line. Soybean seeds of cv. Enrei and the non-nodulated isoline (En1282) were planted alternately in the same row of each plot. Before planting, the seeds were dipped in a culture of *Bradyrhizobium japonicum* (strain USDA 110) (1 X 10^9 cells ml^{-1}). The seeds were planted at a density of 8.9 plants m^{-2} (row distance 75 cm and planting width 15cm) by single stem training. Cultivation method was applied according to the guidebook for soybean cultivation in Niigata prefecture. The total N concentration (TN%) in fertilizers used was CU (40%) and LN (20%).

The growth characteristics of the soybean plants were observed at 61 (R1) and 130 (R7) days after sowing (DAS). The plants were harvested from each plot. Then the shoots were dried for 48 hours in a ventilator oven at 80℃ and dry weight was measured. At the R8 (harvest) stage, ten plants with moderate growth were harvested from each plot. After sufficient drying in a green house under natural conditions, all the pods were carefully removed, and the pod and seed number was counted. Then the seed weight was measured and the seed yield in each plot was calculated. Thereafter, soybean seed quality was classified visually and the number and DW in each group were measured.

Classification of soybean seeds was performed according to the standard classification by Syokuryo-cho, the former Food Policy Organization of Japanese Government (Tewari et al. 2004b), which was as follows:

I. Good seeds: Seeds without diseases, insects, wrinkles, dirt, etc. and with a size over 6.7mm determined by sieving.
II. Small seeds: Seeds with a size below 6.7mm.
III. Purple spot disease: Seeds covered with purple spots with diameter > 3mm.
IV. Brown spot disease: Seeds covered with brown spots with diameter > 3mm.
V. Insect-fed seeds: Seeds with insect-fed cotyledons.
VI. Insect-sucked seeds: Seeds with black spots on the cotyledons.
VII. Pealed coats: Seeds with coats peeled over half of the seed.
VIII. Broken coats: Seeds with coat removed from seed.
IX. Turtle wrinkle: Seed coat wrinkled and appearing as that of a turtle carapace.
X. Side wrinkle: Side of seed coat with vertical wrinkles.
XI. Dirty seeds: Seeds with dirty zones.
XII. Very dirty seeds: Seeds with dirt all around
XIII. Aborted seeds: Immature seeds that were unable to grow to full size.

RESULTS AND DISCUSSION

Fig. 1 shows the changes in DW of total shoot organs, in each treatment at R1 and R7 stages respectively. At R1 stage, the DW of Enrei plants tended to be high in LN+P+K, CU+P and CU+P+K treatments. The difference of shoot DW between Enrei (8-12g) and En1282 (6-11g) was small at R1 stage.

At R7 stage, the DW of Enrei (90-190g) was much higher than En1282 (10-40g), suggesting that nitrogen

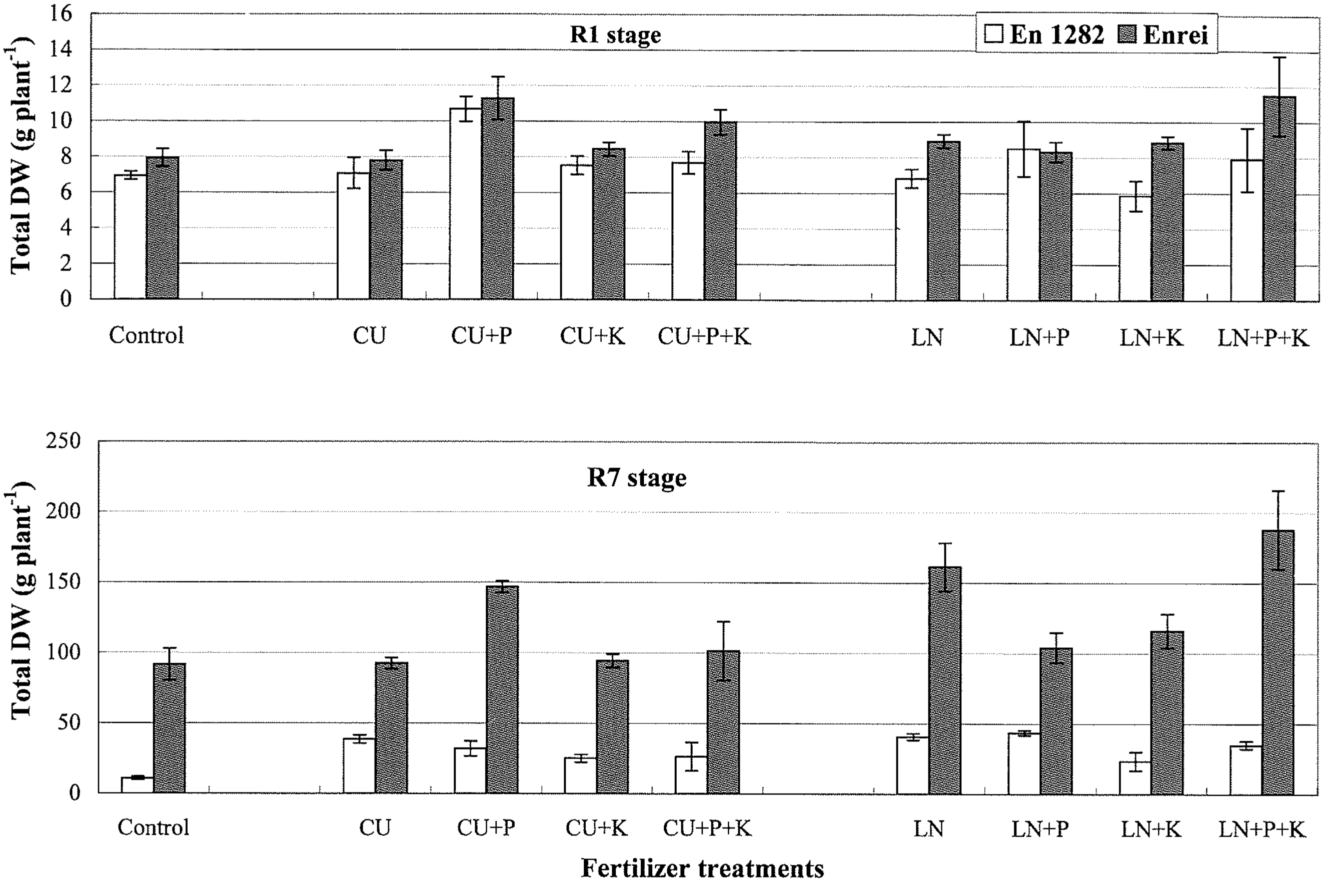


Fig 1. Total shoot dry weight of soybean plant with various fertilizer treatments at R1 and R7 stage (n=4)

fixation activity promoted the plant growth especially after flowering stage. The highest shoot DW was recorded in LN+P+K treatment in Enrei, followed by LN and CU+P at R7 stage. It was found that at R7 stage, the DW of both Enrei and En1282 plants was found to increase with the fertilizer treatments in comparison to control plants, the most notable effect of which was seen in LN+P+K treatment. This suggested that deep placement of slow release fertilizer, LN in combination with P and K fertilizer further promoted the plant growth. Exceptionally the CU+P+K treatment did not give the appreciable increase in DW of Enrei compared with control, which was found to be due to the water logging for some period after rain in that plot. It is well known that water saturation in soil causes oxygen deficiency for nodule respiration and results in depression of nitrogen fixation. The reason for LN+P and LN+K in our experiment that did not promote plant growth compared with LN and LN+P+K is unknown, but it might be due to imbalance of nutrient elements or by the difference in water condition among the plots.

Table 1 shows the growth characteristics of soybean plants, Enrei (Table 1 a) and En1282 (Table1 b) at R7 stage. The stems were slightly longer in the deep placement treatments compared to control, the longest stem being observed in the LN+P+K treatment with Enrei plants. The stem diameter ranged from 10-11 mm respectively in Enrei plants, which show no significance difference among fertilizer treatments. However, the stem length (20-26cm) and diameter (5-7 mm) were significantly low in En1282 due to the lack of nitrogen fixation compared to Enrei. The pod number and pod DW increased by the deep placement of fertilizers compared to the control, the highest number being shown by LN+P+K treatments in both Enrei (110 pods plant^{-1}) and En1282 (31 pods plant^{-1}) plants. Also the values of the seed number (262 seeds plant^{-1}) and seed weight (81.9 g plant^{-1}) were found to be highest in the LN+P+K treatment compared with LN (214 seeds plant^{-1} and 67.8 g plant^{-1}) and control (148 seeds plant^{-1} and 35.6 g plant^{-1}) treatments. It can be noted that the addition of solely P or K fertilizer significantly increased the seed yield in both the slow release fertilizers, LN and CU, compared to the use of LN and CU only, with exception being LN+K. Seed yield per plant in Enrei with LN+P+K (81.9g) value, which is equivalent to 7.30 t per hectare, is regarded as high seed yield in Japan.

Fig. 2 shows the relationship between shoot DW (g plant^{-1}) at R1 stage and R7 stage and that between shoot DW

Table 1 a: Seed yield components of soybean plants (Enrei) at maturity (R7 Stage)

	Main stem length (cm)	Main stem diameter (mm)	Total number of pods per plant	Pod DW (g $plant^{-1}$)	Seed number per plant	Seed weight (g $plant^{-1}$)	Seed weight (g)
Control	45	10.2	80.3	55.1	147.7	35.6	24.1
CU	47	11.2**	90*	60.3**	189.3**	39.8	21.0*
CU+P	48*	11.0**	96*	62.5*	222*	69.3	31.2**
CU+K	45.2**	10.9	91*	60.5*	200.6*	42.7**	21.3*
CU+P+K	46.2	10.8*	87	59	201.7*	43.3*	21.5
LN	48**	11.0	98**	63.1	213.7	67.8**	31.7
LN+P	47.3*	10.9*	99	63.4**	251**	69.9*	27.8**
LN+K	46.2	10.7*	108	67.9	190.3**	55.6	29.2
LN+P+K	48.4**	11.1*	110**	68.6	262.3	81.9**	31.7*

* Data for comparison of the control and fertilizer treatments are different at p=0.05 levels
** Data for comparison of the control and fertilizer treatments are different at p=0.01 levels

Table 1 b: Seed yield components of soybean plants (En 1282) at maturity (R7 Stage)

	Main stem length (cm)	Main stem diameter (mm)	Total number of pods per plant	Pod DW (g $plant^{-1}$)	Seed number per plant	Seed weight (g $plant^{-1}$)	Seed weight (g)
Control	20.1	5.6	22.9	15.7	39.8	5.5	13.8
CU	22.2*	6.3**	25.7*	17.2	66.4	11.3**	17.0
CU+P	23.6*	6.4*	28.3	17.9*	61.4**	10.2*	16.6**
CU+K	24.6**	6.7*	28.3**	17.3**	75.9*	12.8	16.9**
CU+P+K	22.9	5.9**	29.6	18.9	79.6*	10.6	13.3**
LN	26.4*	7.0**	28**	18.0	73.6	11.6**	15.8
LN+P	25.9**	6.8*	28.2	18.1*	81.3**	15.1*	18.6*
LN+K	23.1**	6.6**	30.9*	19.4*	67.3	11.1	16.5
LN+P+K	26.7*	7.1	31.4**	19.6*	87.6*	14.6*	16.7**

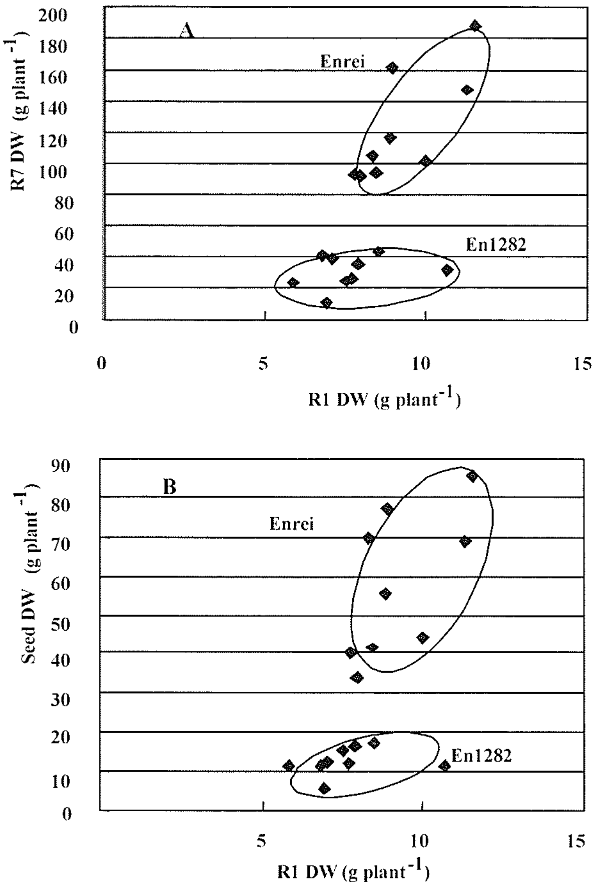
* Data for comparison of the control and fertilizer treatments are different at p=0.05 levels
** Data for comparison of the control and fertilizer treatments are different at p=0.01 levels

at R1 stage and seed yield. Positive correlation was shown between DW (g $plant^{-1}$) at R1 and R7 stages (R^2= 0.473) and that between shoot DW at R1 stage and seed yield (R^2=0.423). This suggests that good vegetative growth before flowering stage affects the shoot growth and seed yield. Non-nodulating line En 1282 could not grow well after R1 and produced poor seed yield due to the lack of nitrogen fixation.

The naked eye examination of harvested seeds was performed and the results are presented in Figs. 3 and 4. Among all the treatments, the highest number of good seeds as well as seed weight was obtained with the LN+P+K treatments in Enrei plants (Fig. 3 a and b). However, in En1282 plants no such noted difference was observed, although there was increase in number of good seeds as well as seed weight in all the fertilizer treatments compared to control plants (Fig. 4 a and b). Among the damaged seeds, the major feature consisted of small seed followed by broken and pealed coat seeds, aborted seeds, seeds with turtle, and side wrinkles. The number of very dirty seeds, seeds with brown spot disease and, purple spot disease seeds were very low, at less than 1%.

Table 2 shows the percentage of visual quality of Enrei (Table 2a) and En1282 (Table 2b) seeds. In Enrei, the control treatment had 69.4% good seed and 1.9% and 9.1% turtle and side wrinkle, respectively. The percentage of good seed was high in CU+P+K (83.6%) and CU (80.2%), due to low percentage of wrinkle seeds in these treatments. Highest percentage of side wrinkle was observed in CU+K treatment (17.2%). However the percentage was relatively low in LN treatments (LN 4.4%, LN+P 7.4%, LN+K 4.3%, LN+P+K 4.2%). This suggests that Ca supply from LN might prevent side wrinkle of soybean seeds. Alternatively, the low Ca/K ratio might cause wrinkle seed coat. The higher percentage of turtle wrinkle in comparison to control (1.9%) was observed in CU+P (8.2%), CU+K (8.4%), LN+P (8.5%) and LN+P+K (11.5%) treatments.

Correlations among percentage of classified seeds were calculated. Positive correlation is observed between % turtle wrinkle and % pealed coat (Fig. 5a, R^2=0.707; ν=0.1%), % turtle wrinkle and % broken coat (Fig. 5b, R^2=0.399; ν=0.1%) and %turtle wrinkle and % side wrinkle (Fig. 5c, R^2=0.294; ν=1%). Negative correlation is observed between % good seed and % turtle wrinkle (Fig. 5d, R^2=0.587) and % small seed and % turtle wrinkle (R^2=0.284). No significant correlation is observed between % turtle wrinkle and % dirty (R^2=0.053), % turtle wrinkle and % very dirty (R^2=0.0002), % turtle wrinkle and % insect fed (R^2=0.039), % turtle wrinkle and % insect sucked (R^2=0.023), % turtle wrinkle and % abortion (R^2=0.119), and % turtle wrinkle and % purple spot disease (R^2=0.027).



The seed yield of soybean depends on dry matter production of shoots, and it requires a continuous supply of large amount of nitrogen. In this experiment, the DW of Enrei and En1282 were not so different at R1 stage. However, the DW and seed yield was significantly lower in En1282 than in Enrei at later stage. This suggests the importance of nitrogen fixation after flowering stage. Therefore, it is necessary to maintain a continuous N assimilation until the maturation stage to obtain a high seed yield (Hoshi *et al.*, 1978; Kato *et al.*, 1983; Harper, 1987). Deep placement of $CaCN_2$ and CU-100 appeared to promote the growth of deep-roots by supplying N in the deep layers of soil, which consequently enhanced the plant growth. The active development of the roots in the deep layers may have enabled them to absorb nutrients and water from the deep layers of soil (Takahashi *et al.*, 1991). In the present experiment, by deep placement of LN+P+K, both fresh weight and dry weight of soybean plants were enhanced compared to control and LN treatments (Fig. 1), presumably due to promotion of vegetative shoot growth by continuous supply of N, P and K after the flowering stage.

It has been suggested that optimum vegetative growth is necessary to obtain an appropriate number of pod sets (Aragaki, 1989). In the present experiment, the yield increase by deep placement of LN+P+K was mainly due to the

Fig 2. Correlation between shoot dry weight at R1 and R7 (A) and between shoot dry weight at R1 and seed dry weight(B).

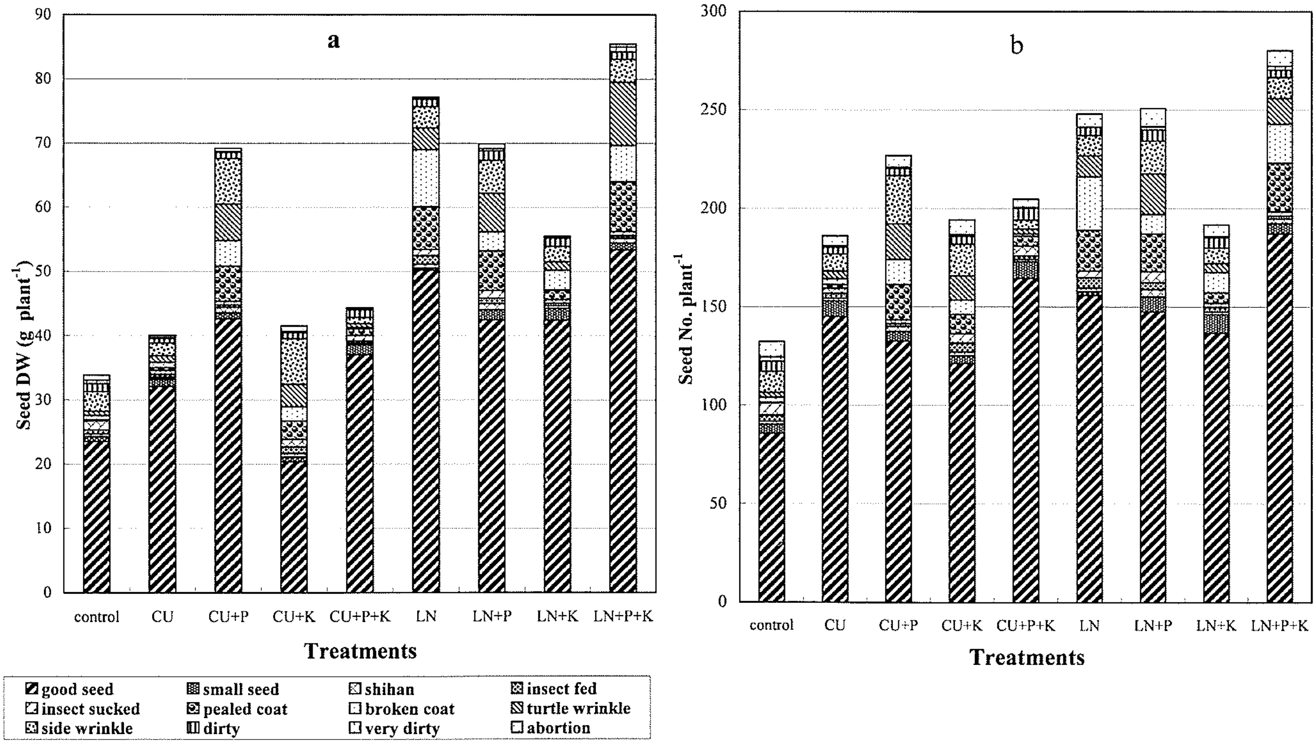


Fig 3. Seed dry weight (a) and seed number (b) of harvested nodulating soybean Enrei classified based on visual grain quality.

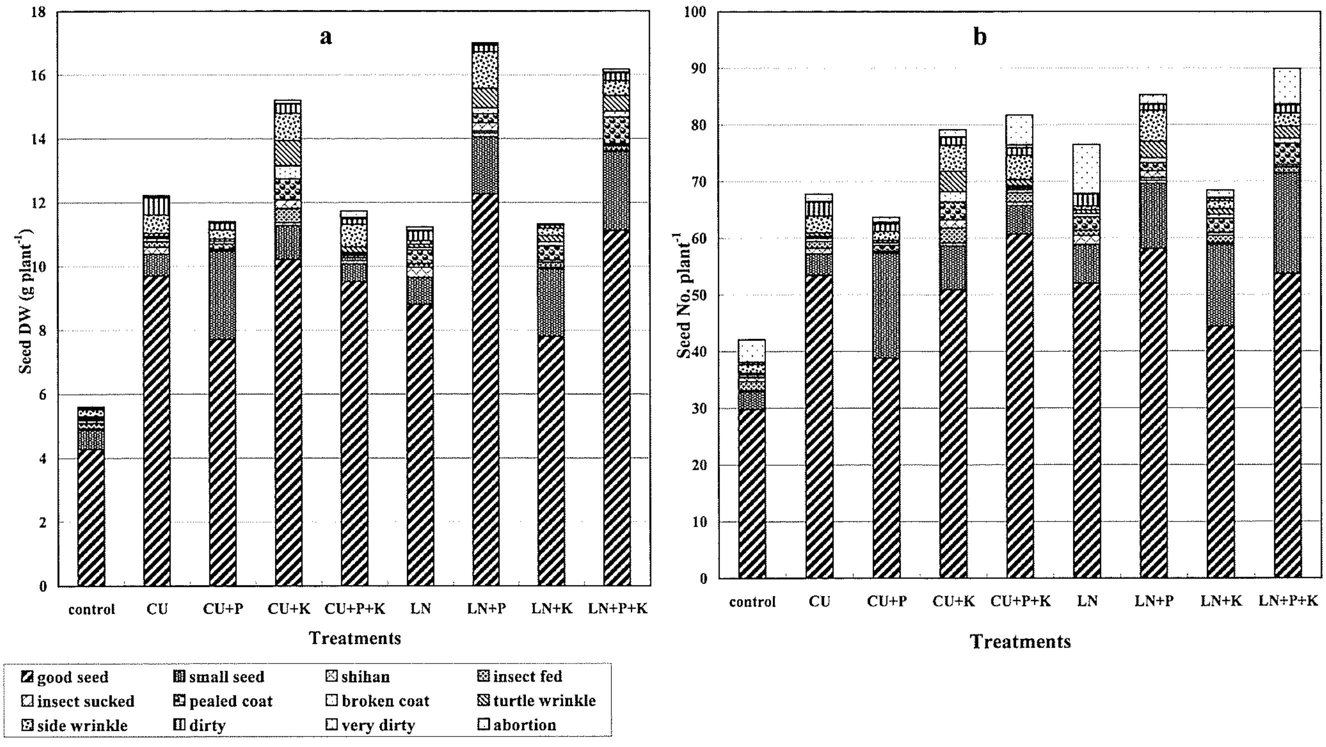


Fig 4. Seed dry weight (a) and seed number (b) of harvested non-nodulating soybean En1282 classified based on visual grain quality.

Table 2a: Percentage of quality classification of Enrei seeds

Treatment	Control	CU	CU+P	CU+K	CU+P+K	LN	LN+P	LN+K	LN+P+K
good seed	69.4	80.2	61.6	49	83.6	65.1	60.8	76.4	62.5
small seed	2.3	2.7	1.4	1.7	3.4	0.4	2.2	3.3	1.2
shihan	1.1	0.8	1.2	1.4	0.6	0.8	1.4	0.7	0.9
insect fed	1.9	1.1	0.6	2.4	0.8	1.7	1.2	0.7	0.5
insect sucked	4.2	1.6	0.8	2.9	2	1.3	1.8	1	0.8
pealed coat	0.2	1	8	6.9	2.3	8.6	8.8	2.7	9
broken coat	2.2	2.1	5.7	5.3	0.5	11.6	4.2	5.5	6.7
turtle	1.9	2.6	8.2	8.4	1.3	4.4	8.5	2.4	11.5
side wrinkle	9.1	4.9	10.3	17.2	2.2	4.3	7.4	4.3	4.2
dirty	3.6	1.7	1.3	2.2	2.6	1.5	2.1	2.3	1.3
very dirty	1.5	0.4	0.2	0.5	0.1	0.1	0.4	0.3	0.9
abortion	2.4	0.8	0.7	2	0.6	0.3	1.2	0.4	0.5

Table 2b: Percentage of quality classification of En1282 seeds

Treatment	Control	CU	CU+P	CU+K	CU+P+K	LN	LN+P	LN+K	LN+P+K
good seed	76.4	79.5	67.6	67.2	81.2	78.4	72.2	69	68.8
small seed	10.8	5.5	24.3	7	4.7	7.4	10.5	18.5	15.3
shihan	0.5	1.8	0.1	0.5	0.9	2.9	0.7	0.5	0.2
insect fed	3.2	1.4	0.1	3	0.8	1.1	0.4	1.4	0.9
insect sucked	1.6	0.9	0.3	1.8	0.5	0	1.5	0.6	0.4
pealed coat	0.5	0.3	1.5	4.4	0.4	3.7	1.7	3.9	5.2
broken coat	1	0.1	0.7	2.7	0.4	0.7	1.1	1.1	1.2
turtle	0.8	0.7	0.6	5.2	1.6	0.9	3.6	1.7	3
side wrinkle	3.7	4.7	2.4	5.6	6.1	1	6.7	2.1	2.9
dirty	0.9	4.4	1.8	1.9	1.4	2.7	1.2	0.6	1.5
very dirty	0	0.3	0.4	0.1	0.5	0.3	0.1	0.3	0.2
abortion	0.7	0.3	0.1	0.7	1.6	1	0.3	0.2	0.5

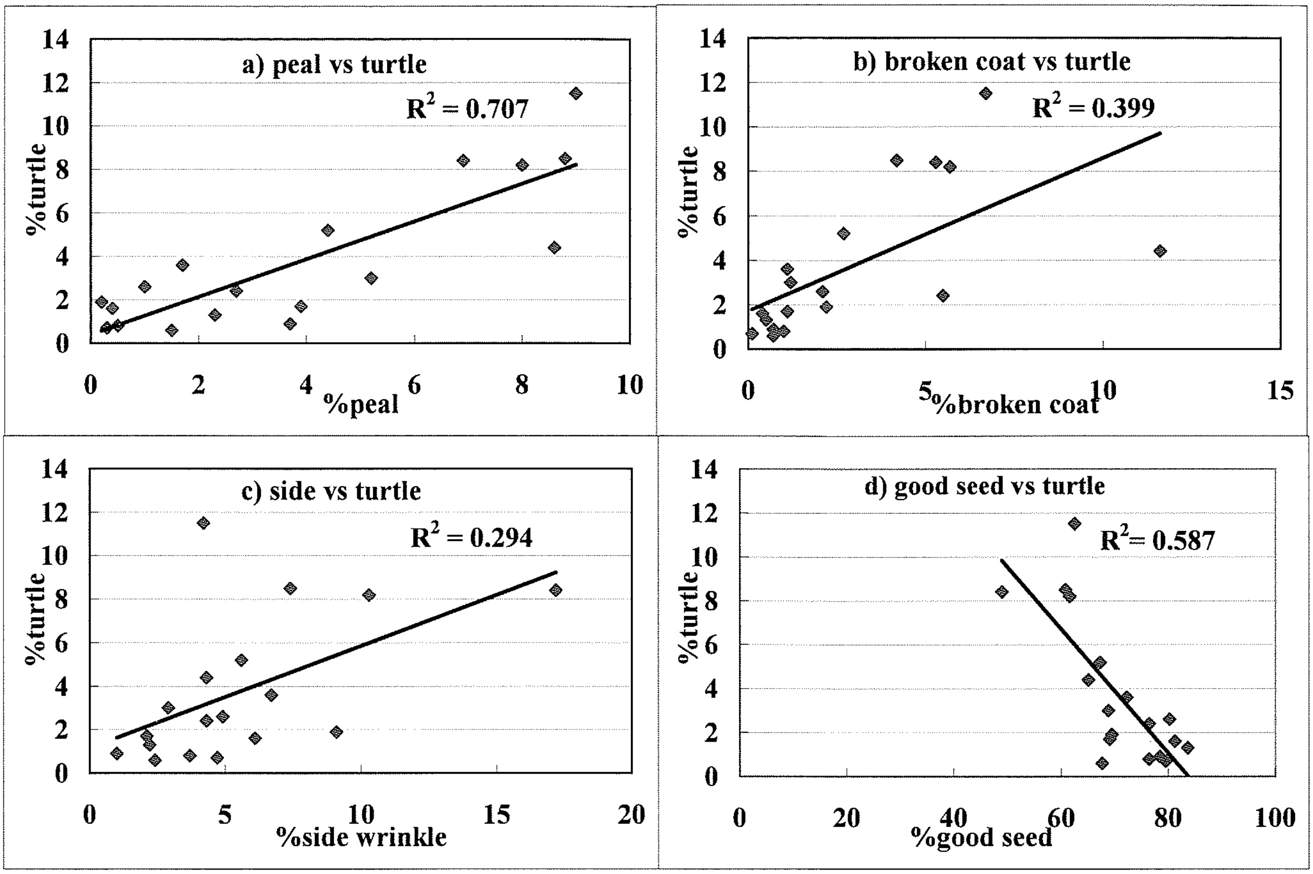


Fig 5. Correlation between turtle wrinkle and other characters of soybean seed quality. (R represents the correlation coefficient)

increase in the pod number per plant (Table 1). Analysis of yield components over the years in continuous cultivation of soybean by Liu and Herbert (2002) showed that the reduction in yield was mainly due to a decrease in the pod and seed numbers per plant.

Soybean diseases are the cause of discoloration and deterioration of seeds. The occurrence of diseases, which contribute to the discoloration of soybean seeds, is usually promoted by warm and humid weather late in the season (Laura, 2002). A preliminary study conducted by Yang (1999) indicated that discoloration by fungi could be enhanced by nutrient deficiencies in soybean. Liu and Herbert (2002) pointed out that continuous cultivation of soybean resulted in a significant increase in diseased and pest-infested seeds, leading to a low quality of seed commodity. Thus crop rotation is an important means of preventing or reducing disease outbreaks. It has been observed that seed coat cracking (peeled coat and broken coat in our experiment) occurs under environments that promote seed size enlargement (Maruyama and Mikoshiba, 1976). Seeds with cracked coats were generally larger than seeds with normal coats (Yaklich and Barla-Szabo, 1993). Sasaki and Sakai (1981) suggested that cracking was caused by an imbalance between the thickness of the seed coats and enlargement of the cotyledons. In our experiment, visual grain quality was not affected by any fertilizer treatments in terms of diseased seeds. Moreover, in terms of good quality seeds, NPK application enhanced the seed yield and the highest yield was recorded in the LN+P+K treatment. This emphasizes the importance of N fertilizer management, for example, deep placement of slow-release fertilizer as well as incorporation of P and K fertilizers, for enhancement of soybean yield and seed quality.

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ダイズ子実収量と品質に対する緩効性窒素肥料（石灰窒素と被覆尿素）、リン、カリウム肥料の深層施肥効果の比較

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要　約

窒素（N）、リン（P）、カリウム（K）は、肥料三大要素であり、しばしば、その供給量が植物生育と作物収量の制限因子になる。これまで、地表下20cmの位置に緩効性窒素肥料（被覆尿素と石灰窒素）を深層施肥する新しい施肥法が、ダイズの生育及び子実収量を増加させることを報告してきた。本研究では、長岡の水田転換畑（新潟県農業総合研究所）において、100kgN ha^{-1}の被覆尿素（CU）または石灰窒素（LN）の深層施肥に加え、熔リン（100kgP_2O_5 ha^{-1}）または、ケイ酸カリウム（100kgK_2O ha^{-1}）を深層施肥することによるダイズの生育と子実収量に対する影響を調べた。根粒着生ダイズ品種エンレイとその非着生変異株En1282を畦に交互に栽培した。処理区は、CU、CU+P、CU+K、CU+P+K、LN、LN+P、LN+K、LN+P+Kと対照区を設けた。エンレイではLN+P+K区で生育がもっともよく、最大の子実収量が得られた。また、子実の外観的な品質についてもLN+P+K区で高品質であった。これらの結果から、緩効性窒素肥料の深層施肥に加えて、PとKの深層施肥を行うことにより、最大収量が得られる可能性が示唆された。しわ粒については、CU+K区でちりめんしわの比率が高かった。亀甲しわの割合は、皮切（R_2=0.707）、剥皮（R_2=0.399）およびちりめんしわ（R_2=0.294）と正の相関がみられたが、整粒（R_2=0.587）とは、負の相関が認められた。

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