การเจริญเติบโตและผลผลิตของข้าวนาหยอดที่ปลูกในระดับความลึกต่างกัน

Seedling establishment and yield of direct-seeded rice under different seeding depths

สุชาดา สานุสันต์[1*], อนันต์ พลธานี[1], สุรศักดิ์ เสรีพงศ์[1], Alain Audebert[2] และ Jean-Claude Mouret[3]

Suchada Sanusan[1*], Anan Polthanee[1], Surasak Seripong[1], Alain Audebert[2] and Jean-Claude Mouret[3]

บทคัดย่อ: การทดลองครั้งนี้มีวัตถุประสงค์เพื่อศึกษาผลของการปลูกข้าวที่ระดับความลึกต่างกัน ที่มีต่อการเจริญเติบโตและผลผลิตของข้าวนาหยอด ทำการทดลองในสภาพเรือนทดลอง หมวดพืชไร่ มหาวิทยาลัยขอนแก่น ปี 2546 ใช้แผนการทดลองแบบ 3 x 5 Factorial in randomized complete block design จำนวน 4 ซ้ำ ปัจจัยที่ศึกษา คือ ระดับความลึกของการหยอดเมล็ดข้าว 5 ระดับ (1, 3, 5, 6 and 7 ซม.) และทดสอบพันธุ์ข้าว 3 พันธุ์ (กข 6 กข 15 และ ขาวดอกมะลิ 105) ผลการทดลองพบว่า การปลูกข้าวที่ระดับความลึกต่างกันมีผลทำให้ เปอร์เซ็นต์การงอก และน้ำหนักแห้งรากที่ระยะ 15 วันหลังปลูกมีความแตกต่างกันทางสถิติ แต่การปลูกข้าวที่ความลึกต่างกันไม่มีผลทำให้ผลผลิตของข้าวแตกต่างกันทางสถิติ แต่มีแนวโน้มว่าการปลูกข้าวที่ความลึก 6 ซม. ให้ผลผลิตข้าวสูงสุด ส่วนพันธุ์ข้าวมีผลทำให้เปอร์เซ็นต์การงอก และน้ำหนักแห้งรากที่ระยะ 15 วันหลังปลูกมีความแตกต่างกันทางสถิติ พันธุ์ กข 6 ให้เปอร์เซ็นต์การงอก และน้ำหนักแห้งรากที่ระยะ 15 วันหลังปลูกสูงกว่าพันธุ์ กข 15 และขาวดอกมะลิ 105 และพันธุ์ข้าวทั้ง 3 พันธุ์ไม่มีผลทำให้ผลผลิตแตกต่างกันทางสถิติ แต่มีแนวโน้มว่า พันธุ์ กข 6 ให้ผลผลิตสูงสุด

คำสำคัญ: ข้าวนาหยอด, การเจริญเติบโตของราก, ความลึกของการหยอดเมล็ด, การงอกของเมล็ด, ผลผลิต

ABSTRACT: The objective of this study is to investigate the effects of different seeding depths on growth and yield of direct-seeded rice. A greenhouse experiment was conducted at the Agronomy Farm at Khon Kaen University in 2003. The experiment was a 3 x 5 factorial in a randomized complete block design with four replications. The two factors were seeding depth (1, 3, 5, 6 and 7 cm) and rice cultivar (three cultivars: RD 6, RD 15 and KDML 105). The results showed that seeding depth significantly affects the percentage of seedling emergence and root dry weight at 15 days after seeding (DAS), but does not significantly affect grain yield. However, planting at 6 cm seeding depth tends to give the highest seed yield. Rice cultivar significantly affects the percentage of seedling emergence and root dry weight at 15 DAS. Using cultivar RD6 gives a higher percentage of seedling emergence and root dry weight at 15 DAS than with RD15 and KDML 105. There is no significant difference in seed yield among the three rice cultivars, but RD 6 generally gives the highest seed yield.
Keywords: Direct-seeding rice, root growth, seeding depths, seedling emergence, yield

[1] Department of Plant Science and Agricultural Resources, Faculty of Agriculture, Khon Kaen University 40002, Thailand

[2] Centre de Cooperation International en Recherche Agronomique pour le Developpement, Aven Agropolis 94398 Montpellier, France

[3] Institut National de la Recherche Agronomique, Place Viala 34060 Montpellier, France

[*] Corresponding author: sanusan@gmail.com

Introduction

Direct seeded is currently a general practice for rice planting in Northeast Thailand. This planting method requires labor than transplanting and can be done even when soil moisture is low. In this region, broadcasting after tillage plowing is used for direct-seeding, and it is commenced after rainfall when the soil is moist (Lantican et al., 1999). Seeds sown by this method are often damaged by birds and rats. This problem can be avoided by deep sowing. However, deep sowing can have adverse effect on seedling emergence and grain yield unless cultivars adapted to deep sowing are used (Hadjichristodou lou et al., 1977: Gill and Prihar, 1989; Kirby, 1993). Seed germination and subsequent seedling develop- ment are crucial in direct-seeding rice regardless of the method of planting. Seed germination is directly related to the depth at which seeds are buried (Huang and Gutterman, 1998: Nie and Zheng, 2005). Shallow sowing usually results in higher seed germination than broadcasting on the soil surface because a moist environment is maintained around the seeds keeping them from drying out (Zaady et al., 1997; Huang and Gutterman, 1998). However, sowing too deep may affect seed germination and prevent seedling emergence. Generally, both seed germination and seedling emergence decrease with increased seeding depths (Liu and Han, 2008). A drill that can effectively penetrate the soil is, thus, requires for direct seeding to place the seeds at the optimum depth for rapid plant emergence (Collins and Fowler, 1996).

Carter (1990) observed that seedling emergence of rice sown at 1 cm depth started four days after sowing and peaked at eight to ten days depending on the rice cultivar. For seeds sown at 5 cm depth, however, peak emergence occurred at 10 days after sowing with no difference between cultivars. Total seedling emergence was found to be significantly correlated with radicle length. Turner et al. (1982) also pointed out that a long mesocotyl is an important characteristic for successful establishment of seeds sown deep in the soil. It appears that seedling growth could be controlled by both sowing depth and rice cultivar. However, under the conditions of Northeast Thailand, it is not know how the currently grown rice cultivars would perform at different planting depths. This information is needed for developing sowing technique and identifying suitable rice cultivars for direct seeding. The objective of this study was to investigate the effects of different depth of sowing on seedling emergence, root development, growth and yield of selected rice cultivars under direct-seeding.

Materials and Methods

The experiment was conducted in a greenhouse at the Agronomy Farm of Khon Kaen University, in Khon Kaen province of Northeast Thailand (16°26'N 102°50' E), from July to November 2003. The mean annual air temperature in the greenhouse was 15.3 to 19.6°C at night and 23.3 to 32.8°C in the daytime. During July, August and September, the accumulated temperature ($\geq$20°C) was 2013.1°C, and the growing season was 150 days. The soil was Typic Halaquepts, with sandy loam texture, (Udon series), 4.65 pH (1:2.5 w/v water), 0.57 percent organic matter content (Walkley and Black, 1934), 250 mg kg^{-1} total N (Kjeldahl method, Bremner, 1960), 13 mg kg^{-1} available P (Bray II extraction, Bray and Kurtz, 1945), and 34 mg kg^{-1} exchangeable K (1 N ammoniumacetate pH 7 extraction, Schollerger and Simmon, 1945).

The experiment was a 3 x 5 factorial in a randomized complete block design with four replications. The two main factors were rice cultivar and seeding depth. The rice cultivars were RD 6, RD

15 and KDML 105, all are photoperiod sensitive cultivars popularly grown in Northeast Thailand. Five seeding depths were used, i.e.1, 3, 5, 6 and 7 cm. A Plastic pot of 210 mm in diameter and 310 mm in height was used as an experimental unit. In total of 180 pots, fifteen treatments were randomly assigned to each block (4 blocks) and each treatment was replicated 3 pots, which sampling recorded at 15 days after seeding for seedlings emergence counted, rice growth, and at harvesting. Twelve kilograms of dry soil was put in each pot. The soil was then wetted to field capacity before planting. A basal fertilizer containing 30 g N pot^{-1} as ammonium nitrate, 30 g P_2O_5 pot^{-1} as triple superphosphate, and 15 g K_2O pot^{-1} as muriate of potash was applied to all pots prior to seeding. The pots were subsequently hand-seeded with the three rice cultivars at the depths of 1, 3, 5, 6, and 7 cm. Fifteen seeds of a rice cultivar were sown in each pot at a particular depth and the seedlings were thinned to 5 plants after emergence. Plants were irrigated as necessary to prevent water stress during growth periods. Urea at 192 g pot^{-1} was applied to all pots as top dressing at panicle initiation stage. No herbicide was applied and weeds were controlled by hand weeding.

Seedlings were counted for emergence at 15 days after seeding (DAS), and were sampled for measurement of root characteristics that included length of coleoptile, mesocotyls, longest nodal root and seminal root. Plants were sampled from ground level to the highest leaf in each pot for leaf area and biomass determination at 15, 30, 45 and 60 days after seeding. Leaf area was measured using a leaf area meter (Model No.AAC.-400, Hayashi Denko Co., Ltd, Japan). Plant samples were dried at 80°C for 48 hours and weighed to obtain biomass. Seed yield was measured by harvesting all five plants in each plot, and seeds were dried to 14 percent moisture before weighing. Yield components were determined panicle number per plant, grains per panicle and thousand grain weight was determined from the filled grains. Data statistical analyses were performed using STATISTICS 8 software (Analytical Software, 2003).

Results

Seedling emergence

Both depths of seeding and rice cultivars differed significantly in seedling emergence, but no interact- tion between the two factors was observed. Seedling emergence was highest at the 1 cm seeding depth, but lower and did not significantly differ at higher depths **(Figure 1).** The emergence rate at the 1 cm seeding depth was 90.1 % compared to 68.6, 66.1, 63.8 and 66.8 % for the 3 cm, 5 cm, 6 cm and 7 cm seeding depths, respectively. Total emergence percentages of RD6 and RD15 seedlings were higher, 74.8 and 73.6 %, respectively than that of KDML105 (65.0 %) **(Figure 1).** Therefore, the KDML105 exhibited a greater seedling emergence rate than that of the RD6 and RD15.

Root distribution and root biomass

Seeding depth and rice cultivar significantly affected root biomass, but not the interaction. The greatest root biomass was obtained at the 1 cm seeding depth (0.12 g plant^{-1}), followed by the 3 cm seeding depth (0.10 g plant^{-1}). At lower seeding depths, root biomasses were lower but did not significantly differ being 0.06, 0.07 and 0.06 g plant^{-1} for the 5 cm, 6 cm and 7 cm depths, respectively **(Table 1).** Root biomass of the RD6 seedling was highest, being 0.09 g plant^{-1}, followed by RD 15 and KDML 105 (0.08 and 0.07 g plant^{-1}), respectively) **(Table 1).**

Seeding depth and rice cultivar also significantly affected root characteristics of rice seedlings, but their interactions were not statistically significant for all root characters. Mesocotyl (first internode) and coleoptiles lengths were short when seeds were sown at a shallow depth and increased as the depth of sowing increased **(Table 1).** Conversely, the lengths of nodal roots and seminal roots were longer at shallow seeding depth (1 cm and 3 cm) than at deeper depths (5 cm, 6 cm and 7 cm). The RD 6 cultivar had longer coleoptile and mesocotyl and shorter nodal and seminal roots than those of RD 15 and KDML 105 cultivars.

Crop growth

Plant height significantly differed among seeding depths and among rice cultivars at 15 and 30 days after seeding, but on differential response of the rice cultivars to different seeding depths was observed **(Figure 2).** The maximum plant height was observed in rice sown at 1 cm and 3 cm depths (33.07 and 32.15 cm, respectively). Conversely, a 7 cm depth produced the lowest plant height value. RD15 rice cultivar gave the highest plant height, followed by RD6 and KDML105 at both sampling dates.

Total above ground biomass and leaf area at 15 days were not significantly affected by different seeding depths, by rice cultivars, the treatments became significantly different at 30 and 60 days, and with no interaction **(Figure 2).** The total above-ground biomass and leaf area at 1 cm and 3 cm seeding depths (Total above-ground: 5.92 and 5.63 g $plant^{-1}$, respectively) were higher than at 5 cm, 6 cm and 7 cm both sampling dates. The rice cultivar RD15 gave the highest total above-ground biomass and leaf area, followed by RD6 and KDML105, at 30 days. But, the lowest leaf area at 60 DAS, though, was observed in RD15.

Seed yield

Seeding depth and rice cultivar did not significantly affect seed yield, number of filled grains per panicle and 1000-seed weight, but significantly affected number of panicles per plant and harvest index. The number of panicles per plant was greater for the 1 cm, 3 cm and 7 cm seeding depths than those for the 5 cm and 6 cm seeding depths **(Table 2).** The average number of panicles per plant ranged from 18.83 to 19.92 for the 1 cm, 3 cm and 7 cm seeding depths compared to 17.17 for the 5 cm seeding depth. Higher harvest index was observed for deeper seeding (3 cm, 5 cm, 6 cm and 7 cm) than for shallow seeding (1 cm). The three rice cultivars were not different in seed yield, number of filled grains per panicle and 1000-seed weight. However, the cultivar RD6 had more number of panicles per plant than the cultivars RD15

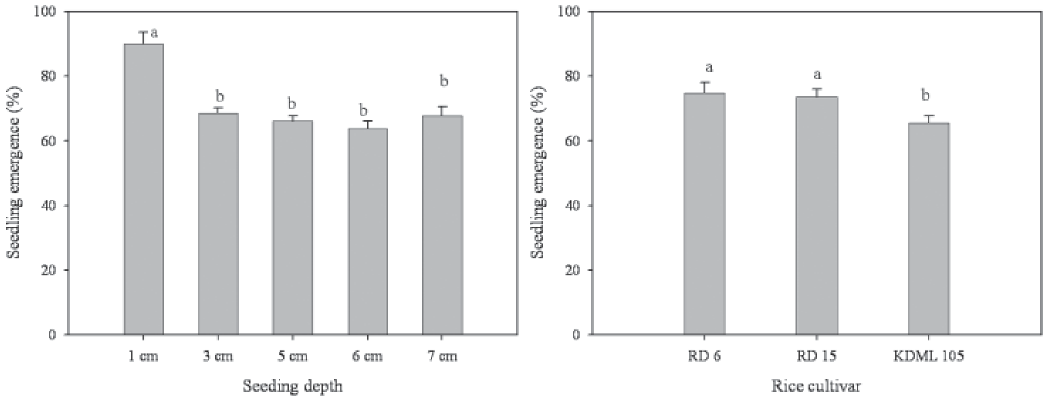

Figure 1 Effect of seeding depth and rice cultivar on percentage of seedling emergence at 15 days after seeding.

Table 1 Root distribution as influenced by seeding depth and rice cultivar at 15 days after seeding.

Treatment	Length (cm)				Shoot biomass (g plant^{-1})	Total root biomass (g plant^{-1})	Shoot : Root
	Coleoptile	Mesocotyl	Nodal root	Seminal root			
Rice cultivar							
RD 6	3.92 a	1.52 c	9.76 a	6.55 b	0.29 a	0.09 a	3.21 a
RD 15	3.30 c	2.39 a	10.98 a	7.36 a	0.28 a	0.08 b	3.50 a
KDML 105	3.60 b	2.04 b	10.83 a	7.48 a	0.25 b	0.07 c	3.57 a
F-test	**	**	ns	**	*	**	ns
Seeding depth							
1 cm	2.32 e	0.89 d	14.20 a	9.00 a	0.35 a	0.12 a	2.92 a
3 cm	2.72 d	1.68 c	12.50 a	6.86 b	0.35 a	0.10 b	3.52 a
5 cm	3.92 c	2.13 b	8.91 b	6.61 bc	0.23 b	0.06 c	3.83 a
6 cm	4.33 b	2.24 b	8.24 b	6.38 c	0.22 b	0.07 c	3.14 a
7 cm	4.78 a	2.98 a	8.77 b	6.78 bc	0.22 b	0.06 c	3.66 a
F-test	**	**	ns	**	**	**	ns
CV (%)	8.86	17.42	21.48	11.88	22.84	17.35	24.33

In a column, mean values followed by a common letter are not significantly difference at the 5% level by Duncan's Multiple Range Test Analysis (DMRT); ns =not significant.

Table 2 Seed yield as influenced by seeding depth and rice cultivar.

Treatment	Panicle (No. plant^{-1})	Filled grain (panicle^{-1})	1000 seed weight (g)	HI	Seed yield (g plant^{-1})
Rice cultivar					
RD 6	20.65 a	77.95 a	24.77 a	0.46 ab	35.24 a
RD 15	16.65 c	79.55 a	24.19 a	0.49 a	33.99 a
KDML 105	18.05 b	79.10 a	24.43 a	0.45 b	34.87 a
F-test	*	ns	ns	*	ns
Seeding depth				0.44 b	
1 cm	19.92 a	78.58 a	24.22 a		34.42 a
3 cm	18.50 abc	79.58 a	23.74 a	0.48 a	35.49 a
5 cm	17.17 c	80.00 a	24.48 a	0.47 a	34.71 a
6 cm	17.83 bc	79.67 a	24.84 a	0.48 a	35.07 a
7 cm	18.83 ab	76.50 a	24.99 a	0.46 ab	33.83 a
F-test	**	ns	ns	*	ns
CV (%)	9.85	8.12	5.42	6.73	9.31

In a column, mean values followed by a common letter are not significantly difference at the 5% level by Duncan's Multiple Range Test Analysis (DMRT); ns =not significant.

and KDML105, while the cultivar RD15 was slightly superior in harvest index than the other two cultivars **(Table 2).**

Discussions

Sowing rice seeds deep into the ground was found to lower seedling emergence. This result agreed with those of other studies, where the importance of

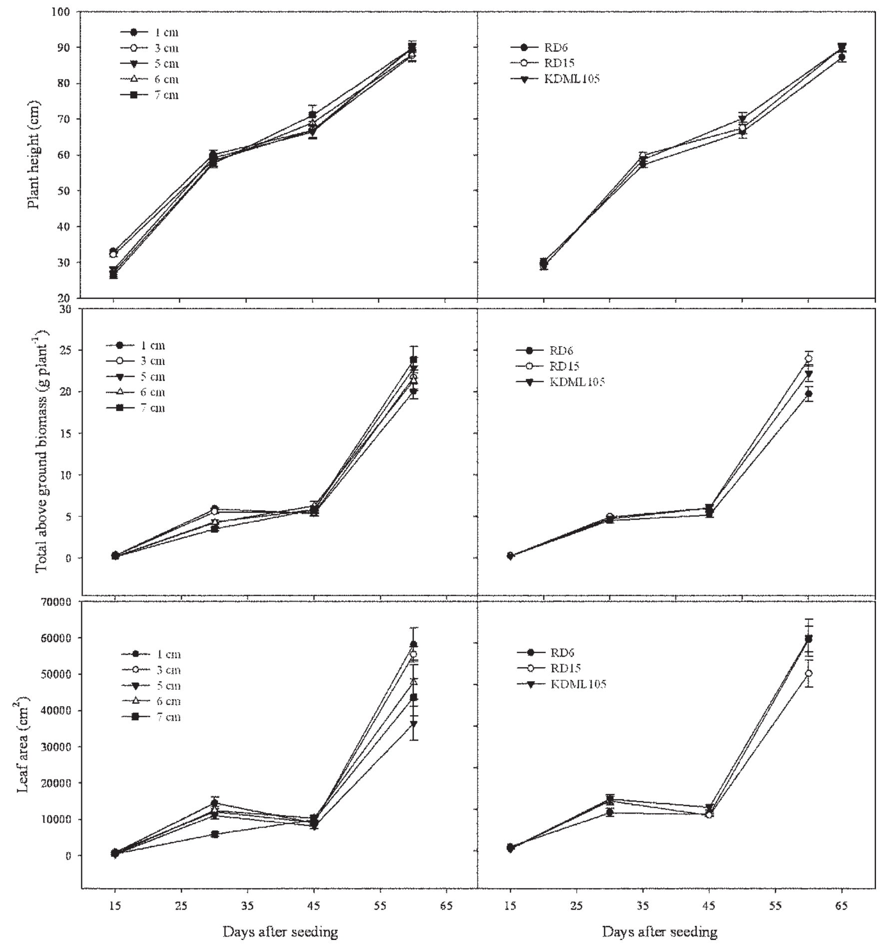

Figure 2 Effect of seeding depth and rice cultivar on plant height, total above ground biomass and leaf area.

seeding depth on the emergence of seedlings has been shown (Campbell et al., 1991; Kirby, 1993; Ouled Belgacem et al., 2006). The fact that the highest mean emergence percentages were recorded at 1 and 3 cm depths indicates that a relatively shallow depth facilitated the emergence of seedlings. Previous studies have found that the critical seeding depth for seedling emergence of rice and wheat was 2.5 cm (Harbir et al., 1991; Collins and Fowler, 1996; Gealy et al., 2000). Lower emergence percentages obtained from 5, 6 and 7 cm depths could be explained in term of exhaustion of energy reserves, thus, preventing seedling from emergence (Boubaker et al., 1999; Boyd and Van Acker, 2003).

In the present study, the rice cultivars also differed in seedling establishment. Such differences among rice cultivars were also observed in other studies (Hanviriyapant et al., 1987; Lantican et al., 1999). The cultivar RD6 showed higher emergence percentage of seedlings than the other two cultivars. However, such an advantage was not applicable in the present study as all the plots were thinned to the same number of plants after emergence.

Seedling emergence was closely associated with the lengths of mesocotyl and coleoptile of rice seedlings. The cultivar RD6 that had a higher seedling emergence percentage also displayed greater lengths of coleoptile and mesocotyle of seedlings than the cultivars RD15 and KDML105. Long mesocotyl and coleoptile were considered an important characteristic of rice cultivars for successful establishment of seeds sown deep in the soil (Yamauchi and Chuong, 1995). Rice breeders hope to obtain genetic resources with optimum coleoptile and mesocotyl lengths to breed rice cultivars with good seedling establishment for direct seeding (Luo et al., 2007). The cultivar RD6 is a semi-dwarf type. Luo et al. (2007) pointed out that the linkage among the genes responsible for mesocotyl and coleoptile lengths and plant height was the major restriction in breeding the semi-dwarf rice cultivars for long mesocotyls and coleoptiles that are desirable for direct-seeding rice.

Plant height, total above-ground biomass and leaf area at an early growth stage were highest in plants seeded at 1 cm or 3 cm below ground than those seeded at greater depths. This was due to the early emergence of plants sown at shallow depths. However, at latter growth stages, plant from different sowing depths showed no difference in these growth characteristics. It seems that the advantage of an early start for shallow sowing did not last long, and plants sown deep could catch up at later growth stage. Consequently, plant from different sowing depths did not differ in seed yield.

The present study was conducted under a well-watered condition. Under natural rainfed conditions where rainfall is erratic, deep seeding is preferred to obtain greater root development, and infrequent rains can put low-depth seeds in danger of drying-up before germination. Nevertheless, the result of the present study indicates that deep seeding which ensures favourable soil moisture and protection against water stress might become an obstacle to seedling emergence. For this reason, Boubaker et al. (1999) suggested that cereals (such as wheat) should be sown deep enough (e.g. 8 cm) so that emergence takes place only after soil is sufficiently wet to ensure the maintenance and growth of the seedlings until reliable precipitation occurs. To compensate for a lower seedling emergence, a slightly higher seeding rate would be needed for direct-seeded rice. However, further studies under rainfed field conditions are needed for deriving appropriate recommendations.

Conclusions

Seeding depth was found to be very important for seedling establishment and seeding growth. Plant from different sowing depths did not differ in seed yield. Rice growth at an early growth stage was highest in plants seeded at 1 cm or 3 cm below ground than those seeded at greater depths. However, sown deep of 5 to 7 cm could catch up at later growth, it is may to avoid risks of seeds drying-out before germination at low depths, and to avoid exhaustion of seedling reserves when seeds are placed too deep in the soil. And RD6 variety cultivar had a higher growth than the cultivars RD 15 and KDML 105, we can improve on the outputs gained from direct-seeded rice.

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