# อิทธิพลของการพรวนดินต่อการเจริญเติบโตและผลผลิตของพันธุ์ข้าวไร่ในภาคเหนือของลาว

# The Effect of Tillage on Performance of Upland Rice Varieties in Northern Laos

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## Abstract

The tradition of farmers in the uplands of Laos is to cultivate upland rice under slash and burn systems by planting rice for only one or two seasons and then allowing the soil to regenerate fertility. However, the recent government policy is to eliminate the slash and burn cultivation and to encourage farmers to adopt more permanent rice cropping systems. Under such continuously cropping of upland rice, the yields become low and unstable. Soil compaction caused by planting without tillage could be one of the factors to decrease upland rice productivity. Therefore, tilling the soil for better root penetration may have the potential to increase upland rice yields in continuously cropped rice systems.

The objectives of this study were (1) to observe whether a mild tillage treatment (soil disturbance around each hill at planting) could increase upland rice productivity as compared to the traditional dibbled planting technique; to determine the performances of five rice varieties grown under such tillage and no-tillage conditions.

The experiment was conducted in 2004 on the plots with the history of continuous planting of upland rice for 2 years at two locations on sloping land in Luang Prabang province, northern Laos. The experimental designs were similar at both locations being a split-plot with three replications. The main plots were under either treated with tillage or no-tillage soil preparations. Sub plot treatments were five upland rice varieties i.e Chaomad, Laboun, Makhinsung, Nok and Vieng.

The result from the experiment did not indicate any significant difference between upland rice yields obtained from tillage or no tillage practices in either location. However, there was a highly significant difference ($P<0.01$) in yields between the five rice varieties under both soil conditions at both locations. "Chaomad" rice variety gave the highest yield in both treatments and both locations. The results of the study also suggest that the current dibble stick technique of planting did not cause soil compaction serious enough to decrease yield of upland rice.

**Keywords:** Continuous cropping, Laos, tillage, upland rice varieties

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# บทคัดย่อ

เกษตรกรในประเทศลาวมักปลูกข้าวไร่ภายใต้ระบบการทำไร่เลื่อนลอย โดยมีการถางป่า แล้วปลูกข้าวเพียง 1 หรือ 2 ฤดู แล้วย้ายไปปลูกในพื้นที่ใหม่ โดยปล่อยให้ดินในพื้นที่เดิมฟื้นฟูความอุดมสมบูรณ์ขึ้นมาอีกครั้ง ในปัจจุบันรัฐบาลลาวมีนโยบายที่จะลดการทำไร่เลื่อนลอยให้หมดไป และส่งเสริมให้เกษตรกรปลูกข้าวในพื้นที่เดิมอย่างถาวร แต่การปลูกข้าวไร่ภายใต้ระบบดังกล่าวอย่างต่อเนื่อง มักทำให้ผลผลิตของข้าวลดลงหรือไม่คงที่ การที่ดินแน่นทึบเนื่องจากเกษตรกรไม่มีการพรวนดินก่อนปลูกอาจเป็นปัจจัยหนึ่งที่ทำให้ผลผลิตข้าวลดลง ดังนั้นจึงตั้งสมมติฐานว่าการพรวนดินจะช่วยให้รากสามารถชอนไชลงไปในดินได้ดีส่งผลให้ข้าวไร่มีผลผลิตสูงขึ้น ถึงแม้ว่ามีการปลูกในพื้นที่เดิมอย่างต่อเนื่อง

วัตถุประสงค์ของงานทดลองคือ (1) เพื่อศึกษาว่าการปลูกข้าวไร่โดยการพรวนดินบริเวณหลุมปลูก (ก่อนหลอดเมล็ด) สามารถช่วยเพิ่มผลผลิตของข้าวได้หรือไม่ เมื่อเทียบกับการปลูกข้าวโดยวิธีดั้งเดิมคือใช้ไม้กระทุ้งดินเป็นหลุมแล้วหยอดเมล็ด (2) เพื่อประเมินการเจริญเติบโตและผลผลิตของข้าวไร่ 5 พันธุ์ ที่ปลูกในสภาพที่มีการพรวนและไม่มีการพรวนดินดังกล่าว

ได้ทำการทดลองในปี พ.ศ. 2547 ใน 2 พื้นที่ปลูก ซึ่งเป็นพื้นที่ที่มีการปลูกข้าวมาแล้ว 2 ปี และเป็นพื้นที่ลาดชันในแขวงหลวงพระบาง ทางภาคเหนือของลาว ทั้ง 2 พื้นที่ใช้แผนการทดลองแบบ split–plot design มี 3 ซ้ำ โดย มีmain–plot คือการพรวนและไม่พรวนดิน และ sub–plot คือข้าวไร่ 5 พันธุ์ (เจ้ามัด, ลาบุญ, หมากหินสูง, นก และเวียง)

ผลการทดลองพบว่า จากทั้ง 2 พื้นที่ปลูก น้ำหนักแห้งและผลผลิตข้าวไม่แสดงความแตกต่างทางสถิติระหว่างการพรวนหรือไม่พรวนเตรียมดิน แต่พบว่ามีความแตกต่างกันทางสถิติอย่างมีนัยสำคัญยิ่ง ($P<0.01$) ระหว่างน้ำหนักแห้งและผลผลิตข้าวทั้ง 5 พันธุ์ โดยข้าวพันธุ์ “เจ้ามัด” ให้ผลผลิตสูงที่สุดทั้งจากการปลูกแบบมีการพรวนและไม่พรวนดิน ผลของการทดลองทำให้ทราบว่าการปลูกข้าวไร่โดยไม่พรวนดินไม่ทำให้เกิดดินแน่นทึบจนถึงระดับที่ทำให้ลดการเจริญเติบโตและผลผลิตข้าวไร่ในพื้นที่ลาดชันทางภาคเหนือของประเทศลาว


**คำสำคัญ:** การปลูกข้าวไร่อย่างต่อเนื่อง การพรวนดิน ประเทศลาว พันธุ์ข้าวไร่

## Introduction

The tradition of farmers in the uplands of northern Laos is to cultivate upland rice and other crops under slash and burn systems. Normal upland rice is planted for only one or two years, using traditional varieties, and a traditional, no–tillage dibble stick technique for planting (Roder, 2001). The current policy of the government is to eliminate slash and burn cultivation and to encourage farmers to adopt more permanent rice cropping systems.

The current conditions of declining fallow lengths, decreasing soil fertility and increasing weeds infestation contribute to low rice yields. The results of some experiments conducted in Luang Prabang indicated that when upland rice is continuously cropped, the yields declined by 47 and 62 % in the second and third season, respectively, when compared to the yields in the first year (Roder et al., 1995). The causes of decreasing rice yields in continuously cropped upland rice are not well understood (Saito, 2005). Such causes might include nutrients loss by leaching, crop removal and other losses (Sanchez, 1976), weed competition and/or nematodes (Roder, 2001), other pests or diseases, and increased soil compaction (Husson et al., 2001, Kyuma and Pairintra, 1983).

Soil compaction can reduce plant growth, root penetration, and development of plant root systems. Restriction of water flow in the soil by compaction could cause nutrient stress in the growing crop (Bengough, 1988). Dolan et al. (1992) reported that soil compaction reduced P and K uptake by the crops planted in later years of continuous cropping. Compaction usually reduces the volume of pores in the soil and may restrict root growth because of increased mechanical resistance and/or poor aeration. Root diameter may decrease as root growth is restricted by narrow holes in the soil (Dexter, 1986). Therefore, any tillage practice in upland rice cultivation system should increase root penetration into deep soil layer, enhancing root development and controlling some soil-borne insect pests (Gajri et al., 2002).

The objectives of this study were (1) to observe whether a mild tillage treatment (soil disturbance each hill at planting) could increase upland rice productivity as compared to the traditional dibbled plating technique; (2) to determine the performances of five rice varieties grown under such tillage and no-tillage conditions.

## Materials and Methods

This experiment was conducted during the 2004 wet-season at two locations in Luang Prabang province, northern Laos. The two locations were Northern Agricultural and Forestry Research Center located at Houay Khot (HK) and a farmer's field at Tin Pha (TP) village. The experimental plots at both locations were fallowed for 2 years from 2000-2001 and were planted with upland rice in 2002 and 2003. Therefore, both experimental plots were planted with upland rice in three consecutive years from 2002-2004. Table 1 describes the main characteristics of these experimental sites.

**Table 1 Characteristics of experimental sites selected for testing tillage practice on five upland rice varieties**

| Location | Cropping history | Slope (%) | Elevation (masl)* | Soil type** | Annual rainfall (mm)*** |
|---|---|---|---|---|---|
| **Houay Khot** | 2 years rice | 27 | 350 | Eutric Cambisol | 1300 |
| **Tin Pha** | 2 years rice | 35 | 670 | Haplic Acrisols | 1400 |

*masl-meter above sea level

**Soil Survey and Land Classification Center (2002)

***Average of 20 years (1986-2005)

The soils at both locations are acidic and have high clay contents (Table 2). Organic matter (OM) and total nitrogen (N) in TP were higher than in HK. Available phosphorous (P) was low in both locations. In contrast to OM and N, available potassium (K) in HK was higher than that in TP.

The experimental design at both locations was a split-plot with three replications. The treatments on the main plots were soil disturbance (tillage) and no soil disturbance (no tillage) at planting. Soil disturbance was done at planting time by digging up a 20 cm. by 20 cm. at the depth of 15 cm. before putting 10-15 rice seeds at 2 cm. depth at the center. The no-tillage technique was done by using the traditional dibble stick to makes the holes at 3-4 cm. depth before placing rice seeds. The sub plot treatments consisted of five upland rice varieties: Chaomad (CM), Laboun (LB), Makhinsung (MS), Nok (NK) and Vieng (VG). The sub-plot size was 1x5m. All rice varieties were planted on May 11, 2004 at TP and May 19, 2004 at HK.

Rice was planted at the spacing of 25x25 cm. between hills with the seeding rate of 60 kg/ha. During the growing season, rice plots were hand-weeded 3 times in both locations. LB, NK and VG varieties were harvested on September 30, 2004, whereas CM and MS were harvested on October 6, 2004 at TP. At HK, LB, NK and VG were harvested on September 15, 2004, CM and MS on October 4, 2004.

**Table 2 Physical and chemical properties of soils at the experimental sites (Houay Khot and Tin Pha), Luang Prabang province**

| Soil properties | Houay Khot | Tin Pha |
|---|---|---|
| Physical properties[1/] | | |
| Sand ( %) | 22 | 22 |
| Silt (%) | 37 | 24 |
| Clay (%) | 41 | 54 |
| Chemical properties | | |
| pH (1:2.5 $H_2O$) | 5.17 | 4.55 |
| OM (%)[2/] | 2.00 | 4.15 |
| Total N (%)[3/] | 0.17 | 0.25 |
| Available P (mg/kg)[4/] | 7.5 | 6.0 |
| Available K (mg/kg)[5/] | 236 | 88 |

[1/]Hydrometer method, [2/] Hence method, [3/] micro-Kjeldahl method, [4/] Olsen method, [5/] 1N ammonium acetate pH 7.0.

The root penetration resistance (RPR) of the soil was measured once a month from planting time to 50% flowering using the "Lang" penetrometer (V. J. Tech Ltd. Material Testing Equipment for Soil, Concrete & Asphalt). Measurements were made, to a maximum depth of 20 cm. at 10 hills randomly selected in each main plot at the area where the soil had been disturbed. The root penetration resistance (RPR) was expressed as kg/cm.[2] (Donald, 1965) and calculated using (Lang, 1987) equation as follows:

$$RPR = (Measured\ value-1\ )\ X\ 2.334$$

At harvest, plant roots were also scored for the presence of root aphid (*Tetraneuta nigriabdominalis*) by randomly pulling 10 rice hills in each plot to check the roots for aphid infestation. If aphids were present (even with only one aphid), the score was 1, if there was no aphid the score was 0. The scores were used to calculate the percentage of root aphid affected hills. At the same time root-knot nematode (*Meloidogyne graminicola*) infestation was also examined in the plants pulled from randomly selected hills.

At rice maturity, rice plants from five representative hills per plot were cut at the ground level to determine dry weight, harvest index (HI) and yield components. Rice grain was measured in the harvest area (0.5x4 m) by stripping the grain from the panicle, and grain yields were reported at 14% moisture content.

The experimental data was analyzed by the analysis of variance (ANOVA) and comparison of means (Gomez and Gomez, 1984), using the statistical program "STATISTIX 8" (Analytical Software, 2003) for each individual experiment and combined analysis was done across locations.

## Results

Rice grain yields of the five varieties were higher at HK than at TP (Fig. 1). The tillage treatments did not have any significant effect on rice grain yields at either site. Average yields for no-tillage and tillage treatments, respectively, at HK ranged from 1.1 to 2.6 and 0.7 to 2.3 t/ha and at TP 0.2 to 1.7 and 0.3 to 1.5 t/ha (Fig. 1). There were significant differences in grain yields between the five upland rice varieties. CM gave significantly higher yield in both treatments at both locations. The yields of CM were higher than those of LB, MS, NK and VG varieties, respectively by 75, 158, 96 and 252 at HK and 162, 287, 173 and 558% at TP.. All rice varieties at HK had a tendency to give higher grain yields under no-tillage when compared to tillage treatments, with the exception of MS. There was no significant interaction between soil treatments and yields of rice varieties in either location.

Combined analysis of variance indicates a significant difference in grain yield between locations. Average yields at HK were 117%

higher than at TP. There was a significant variety effect on yields and varieties behaved similarly at both locations with the highest yields being CM (2000 kg/ha) followed by LB (1000 kg/ha), MS (857 kg/ha), NK (666 kg/ha) and VG (599 kg/ha). Of these varieties, CM had the highest HI (0.33) compared to the other varieties (Table 3). The total dry weight at HK was significantly higher than that at TP. CM had the highest grain yield and total dry weight compared to other varieties at both locations (Table 3).

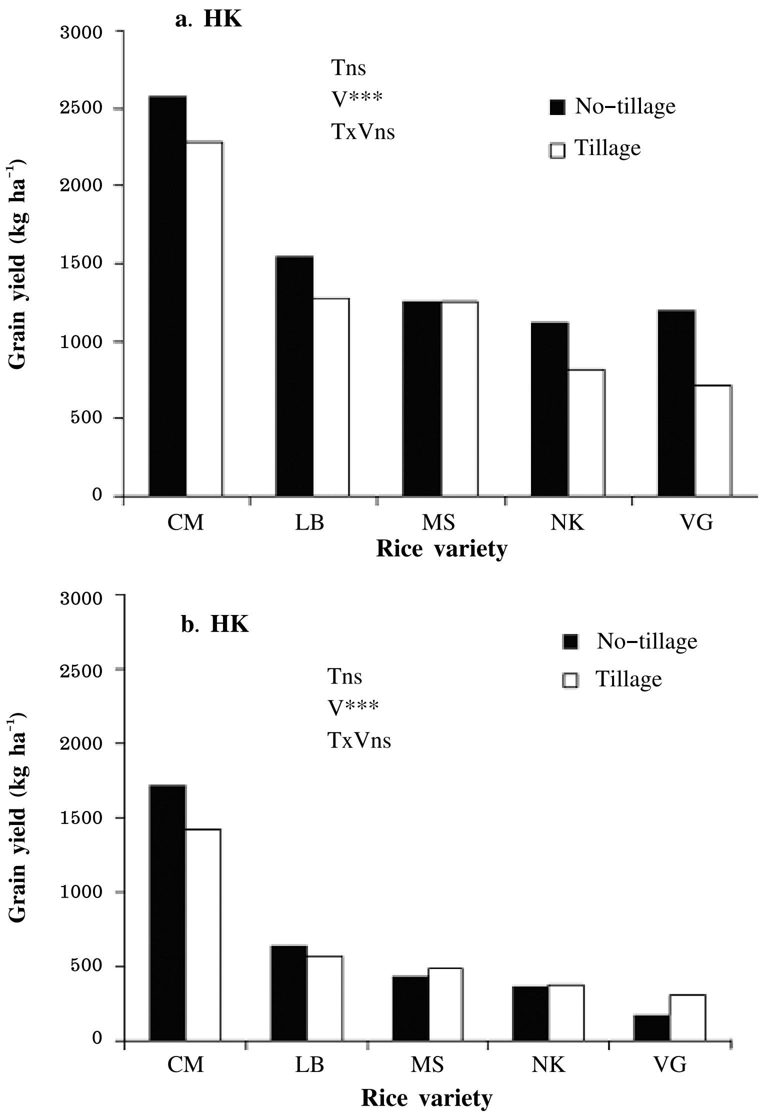


**Fig. 1 Grain yields of five upland rice varieties as affected by tillage in (a) Houay Khot and (b) Tin Pha, Luang Prabang province. Values presented are the means of three replications. CM-Chaomad, LB-Laboun, MS-Makhinsoung, NK-Nok, VG-Vieng. T-treatment, V-variety.**

The only significant interaction effect for the four measured parameters was a location x treatment x variety interaction on HI (Table 3). This indicated that the HI of the five rice varieties changed with tillage treatment and location.

The percentage of root aphid affected hills at HK was significantly higher than that at TP (72 vs 17% of total hills). The reason for this difference is not known. Significant differences in the percentage of root aphid infestation were also observed between the

**Table 3 Grain yield, total dry weight, harvest index (HI) and root aphid infestation of five upland rice varieties under two tillage treatments at two locations in Luang Prabang province**

| | Grain yield[1/] (kg/ha) | Total DW (kg/ha) | HI | Root aphid infested hill (%) |
|---|---|---|---|---|
| **Location** | | | | |
| Houay Khot | 1403 a | 4818 a | 0.30 a | 71.67 a |
| Tin Pha | 647 b | 1643 b | 0.25 b | 17.33 b |
| **Treatment** | | | | |
| No-tillage | 1101 | 3365 | 0.28 | 47.00 |
| Tillage | 949 | 3097 | 0.26 | 42.00 |
| **Variety** | | | | |
| Chaomad | 2000 a | 5330 a | 0.33 a | 41.66 ab |
| Laboun | 1005 b | 3013 b | 0.28 b | 33.33 b |
| Makhinsung | 857 bc | 2985 b | 0.25 b | 47.50 a |
| Nok | 666 c | 2546 b | 0.25 b | 49.17 a |
| Vieng | 599 c | 2281 b | 0.25 b | 50.83 a |
| **Mean** | **825** | **3231** | **0.28** | **42.30** |
| **ANOVA summary** | | | | |
| **F-test**: Location(L) | * | * | * | * |
| Treatmen (T) | ns | ns | ns | ns |
| Variety (V) | ** | ** | ** | * |
| L x T | ns | ns | ns | ns |
| L x V | ns | ns | ns | ns |
| T x V | ns | ns | ns | ns |
| L x T x V | ns | ns | * | ns |

[1/] 14 % moisture content ns-not significant

* significant at the P<0.05 level

** significant at the P<0.01 level

Values in column followed by the same letter are not significantly different at 5% level different rice varieties which ranged from 33 to 51%. LB had the lowest percentage of root aphid infestation, which was statistically different from MS, NK and VG, although not from CM. CM was the highest yielding variety but had the same percentage of root aphid affected hills as the lower yielding varieties (Table 3).

Yield components of the five rice varieties grown at the two locations are shown in Table 4. There was no significant effect of tillage treatment on the four measured yield components. Significant differences between varieties were observed in all the four measured parameters, with the exception of grain number per panicle at TP. CM had a higher number of harvested hill per $m^2$, panicle number per hill and was among the top varieties in grain number per panicle but lowest in 1000 grain weight in both locations. MS, NK and VG had lower numbers of harvested hills, and panicle number per hill, but higher in number of grains per panicle and 1000 grain weight at both locations (Table 4). When combined analyses of the yield components across sites were made, significant difference between locations was observed only in number of grains per panicle; i.e HK had significantly greater number of grains per panicle than that at TP (Table 4). No significant effect of treatments on the four measured parameters were observed. Significant variety effects were observed in all parameters. CM was among the top varieties in number of harvested hill per $m^2$, number of panicles per hill and number of grains per panicle but was the lowest in 1000 grain weight. While MS, NK and VG were the lowest in number of harvested hill per $m^2$ and number of panicles per hill but were the highest in number of grains per panicle and 1000 grain weight (Table 4). Treatment x variety and location x treatment x variety interactions were significant only in panicle number per hill and grains per panicle (Table 5).

Root penetration resistance was significantly higher at HK than that at TP (Table 6). Soil disturbance reduced the root penetration resistance of soil throughout the growing season. The mean of root penetration resistance for the tilled soil was half of that of non-tilled soil (7.71 vs 18.69 kg/cm$^2$) and there were highly significant differences in June and July (14.90 and 15.83 kg/cm$^2$).

## Discussions

*Effect of tillage soil*

The results of this study did not show any significant difference on upland rice yields between tillage and no-tillage treatments. Similar findings were also reported by Nyoka (1983), Lal and Dinkins (1979) and Hayashi et al. (1996). These results do not support the hypothesis that increased soil compaction from continuous cropping of rice in upland areas will result in low yields because of poor root growth and

**Table 4** Yield components of five upland rice varieties as affected by tillage and no-tillage treatments at two locations (HK and TP), Luang Prabang province in 2004

| | Houay Khot | | | | Tin Pha | | | |
|---|---|---|---|---|---|---|---|---|
| | Number of harvested hills per $m^2$ | Number of panicles per hill | Number of grains per panicle | 1000 grain weight (g) | Number of harvested hills per $m^2$ | Number of panicles per hill | Number of grains per panicle | 1000 grain weight (g) |
| **Treatment** | | | | | | | | |
| No-tillage | 12 | 5 | 89 | 33.42 | 11 | 6 | 58 | 32.43 |
| Tillage | 12 | 4 | 79 | 32.65 | 12 | 4 | 54 | 32.54 |
| **Variety** | | | | | | | | |
| Chaomad | 16 a | 8 a | 91 ab | 27.38 c | 16 a | 10 a | 61 | 27.97 d |
| Laboun | 15 a | 6 b | 64 c | 29.24 c | 14 a | 7 b | 48 | 29.17 c |
| Makhinsoung | 10 b | 2 c | 92 a | 37.80 a | 8 b | 3 c | 52 | 35.74 a |
| Nok | 10 b | 2 c | 76 bc | 37.56 a | 9 b | 3 c | 56 | 36.20 a |
| Vieng | 10 b | 3 c | 96 a | 33.21 b | 10 b | 3 c | 62 | 33.36 b |
| **Mean** | **12** | **5** | **84** | **33.03** | **12** | **5** | **56** | **32.48** |
| **F-test** | | | | | | | | |
| Treatment (T) | ns | ns | ns | ns | ns | ns | ns | ns |
| Variety (V) | ** | ** | ** | ** | ** | ** | ns | ** |
| TxV | ns | ns | ** | ns | ns | ** | * | ns |

ns-not significant

* significant at the P<0.05 level

** significant at the P<0.01 level

Values in column followed by the same letter are not significantly different at 5% level

**Table 5 Combined analysis of yield components of five upland rice varieties under tillage and no-tillage treatments at two locations in Luang Prabang province**

| | Harvest hill (no/m²) | Panicle per hill | Grain per panicle | 1000 GW (g) |
|---|---|---|---|---|
| **Location** | | | | |
| Houay Khot | 12 | 4 | 84 a | 33.04 |
| Tin Pha | 11 | 5 | 56 b | 32.48 |
| **Treatment** | | | | |
| No-tillage | 11 | 5 | 71 | 32.88 |
| Tillage | 12 | 4 | 69 | 32.64 |
| **Variety** | | | | |
| Chaomad | 16 a | 9 a | 76 a | 27.67 d |
| Laboun | 14 a | 7 b | 56 c | 29.21 c |
| Makhinsung | 8 b | 3 c | 72 ab | 36.77 a |
| Nok | 9 b | 3 c | 66 b | 36.87 a |
| Vieng | 10 b | 3 c | 79 a | 33.28 b |
| **Mean** | **12** | **5** | **70** | **32.56** |
| **ANOVA summary** | | | | |
| F-test: Location (L) | ns | ns | ** | ns |
| Treatment (T) | ns | ns | ns | ns |
| Variety (V) | ** | ** | ** | ** |
| L x T | ns | ns | ns | ns |
| L x V | ns | ns | ns | ns |
| T x V | ns | ** | ** | ns |
| L x T x V | ns | ** | ** | ns |

ns-not significant

** significant at the $P<0.01$ level

Values in column followed by the same letter are not significantly different at 5% level

limited availability of water and nutrients to the rice plants (Bengough, 1988; Gupta and O'Tool, 1986). Stone et al. (1980) reported that non-tilled soils restricted root development in upland rice and reduced grain yield. However, in upland rice cultivation systems on sloping lands in Laos, land preparation is done by hand and soils are not as compact as those prepared by machines. Although the data on root penetration resistance showed a significant difference between tillage and no-tillage treatments the soil compaction under such conditions did not appear to affect upland rice productivity in either HK or TP. It is noted that all values of root penetration resistance measured at both locations were lower than

**Table 6 Root penetration resistance (kg/cm²) of soil in no-tillage and tillage treatments at two locations in Luang Prabang province, in 2004**

| | Root penetration resistance (kg/cm²) |
|---|---|
| **Location** | |
| Houay Khot | 15.34 a |
| Tin Pha | 11.06 b |
| **Treatment** | |
| No-tillage | 18.69 a |
| Tillage | 7.71 b |
| **Month measurement** | |
| May (at planting) | 8.28 c |
| June | 14.90 a |
| July | 15.83 a |
| August | 13.80 b |
| **Mean** | **13.20** |
| F-test: Location (L) | ** |
| Treatment (T) | ** |
| Month (M) | ** |
| L x T | ns |
| L x M | ** |
| T x M | ** |
| L x T x M | ns |

ns-not significant
** significant at the $P<0.01$ level
Values in column followed by the same letter are not significantly different at 5% level

the critical value (33 kg/cm²) (Lang, 1987). The irrespective of tillage treatments. The values of root penetration resistance were higher in HK than that at TP for both no-tillage and tillage treatments because of the differences in soil type between the two locations. The soil at HK is Eutric Cambisols, but the soil at TP is Haplic Acrisols (Soil Survey and Land Classification Center, 2002). Gupta and O' Tool (1986) suggested that deeply plowed soil has a lower bulk density, which might improve root development and increase yield due to better soil structural stability and reduced erosion. In contrast, our findings indicate that lower root penetration resistance resulted from the tillage treatment did not increase grain yield of upland rice but the tillage practice seemed to reduce it. This might be due to other factors such as soil erosion and soil moisture. It was observed that soil erosion occurred more in the plots with tillage treatment than the no-tillage treatment at the beginning of the season, especially at TP. This has been previously reported by Hayashi et al (1996). In addition, soil which is more friable as indicated by lower root penetration resistance, may result in more water losses via seepage and evaporate from the root zone (Gupta and O' Tool, 1986). The water loss might occur at TP where soil aggregates are larger. Such loss may lead to the conditions of water deficit and low nutrient availability for plant growth, especially during plant establishment.

One reason for lower rice grain yields at TP than those at HK might be due to lower pH, available P and K at TP than those at HK. The levels of organic matter and nitrogen would not necessarily limit rice productivity, while P might be a limiting factor at both locations (Ventura and Watanabe, 1978).

*Yield performance of upland rice varieties*

Among the five rice varieties, CM gave significantly higher yields than other upland rice varieties in both soil treatments and locations. One reason why CM may have a higher yield than the other varieties could be because it has more number of harvested hills per $m^2$, more panicles per hill and more grains per panicle. Another reason why CM produce higher yield than the other four varieties was better resistance to root aphids. During the growing season, all varieties were infested by root aphids (*Tetraneuta nigriabdominalis*) from 30 days after planting, and its infestation continued until harvest. During that period, many rice plants of MS, NK and VG varieties, died, however, fewer CM plants died. Such infestation led to reduced number of rice hills per $m^2$ at harvesting. Root aphids have been reported to be a contributing factor to reduce grain yields of upland rice (Van Keer, 2003). The third reason why the yield of CM was not reduced when compared to the other varieties in continuously cropped soil conditions could be the difference in the form of the root systems among different varieties (Pavlychenko, 1937; Hayashi and Shigenega, 1993). Sengxua (2007) reported that CM had higher root number and lenght than the other four varieties.

The 1000 grain weights of CM and LB were relativity low (28g and 29g, respectively) compared to those of MS, NK and VG, which were between 33-37g, Therefore the better yield performance of CM than the other varieties was from other yield components rather than 1000 grains weight. It should be noted that the seeding rate in the experiment was 60 kg/ha, and therefore more seeds were planted per hill for CM (14 seeds) than for MS, NK and VG (10 seeds). In addition, CM seemed to germinate and survive better than NK and VG. It had higher number of harvested hills per $m^2$ (16 hills) than NK and VG (10 hills) and almost triple of the number of panicles per hill (8 panicles) more than those two varieties (2 and 3 panicles). These latter two varieties had the lowest grain yields in both locations. The other reason for their poor performance might be because they are more susceptible to root aphid infestation (49-51%).

Roder (2001) reported that root-knot nematode infestation was a cause of poor yield in upland rice, but in our studies root-knot nematode infestation was evaluated at final harvest and no infection was observed in any varieties in either location.

## Conclusions

Upland rice production on land cropped continuously for 2-3 years in northern Laos, did not seem to be affected by soil compaction, especially during the rainy season. Therefore, a no-tillage system, as farmers in Laos currently practice, seems to be the best method for sloping land areas. Tilling soil did not increase upland rice yield, but did increase the cost of land preparation and soil erosion.

There were significant differences in yields between the five rice varieties under continuously cropped systems, and therefore the selection of appropriate rice varieties is likely to play an important role in maintaining sustainable rice production in more intensive agriculture systems.

Among the five varieties tested in this experiment, CM gave the highest yield and appears to be more suitable for continuously cropped rice systems in northern Laos. Selection criteria for selecting good varieties for continuous cropping upland rice system should be based on their root systems and the recommended varieties should be diverse for alternative rotational systems (using different variety in each season). This would help to reduce pest and disease problems in continuously cropped rice systems.

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