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Growth, yield components, agronomic traits, kernel yield, cost and benefit of the NK48 corn genotype grown in tillage and no-tillage soils with different rice residue management practices

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The objective of the study was to assess growth, yield components, agronomic traits, kernel yield, cost and benefit of the NK48 corn genotype grown in no-tillage with the uncut rice ratooncovered with rice straw (T1), no-tillage with the cut rice ratoon covering (T2), no-tillage with the uncut rice ratoon(T3), and tillage without any covering (T4). The significantly highest total plant dry weight in T1 was attributed to leaf dry weight, stalk dry weight, tassel plus peduncle dry weight, cob dry weight, husk dry weight, and kernel dry weight compared to the rest of the treatments. Plant growth under T1 was better than those under T2, T3, and T4 in terms of stalk length, tassel plus peduncle length, plant height, and ear height. The amount of the total plant water accumulation in T1 was significantly higher than those in T2, T3, and T4, mainly due to its greater water accumulation in all the stalks, leaves, kernels, cobs, and husks. The % total plant water accumulation was similar in all the 4 treatments (T1, T2, T3, and T4) ranging from 57.1 – 60.6%. Overall, the % water accumulation in the stalks in all the 4 treatments was the highest followed by the % leaf water accumulation, the % kernel water accumulation, the % cob water accumulation, and the % husk water accumulation, respectively. T1 gave significantly the highest kernel yield compared with those of the rest treatments, mainly due to the more kernel number per row and kernel number per ear, and heavy 1,000-kernel weight. No-tillage with the uncut rice ratoon covered with rice straw (T1) increased the corn kernel yield by 35.2% as compared to tillage without any covering (T4, the control treatment). Sink strength index (SSI) is more applicable value used to describe the translocation of assimilates from the source or storage organs or source and storage organs into the ear than harvest index (HI) value. The highest cost of production was under T1. This could compensate with the highest benefit, resulting in the highest net profit (36,369 baht/ha) due to the significantly highest kernel yield (10.37 t/ha) under T1. The lowest net profit (8,523 baht/ha) was under T4 due to the high production cost and the lowest kernel yield (6.72 t/ha). Therefore, the production of the NK48 corn genotype under T1 was the most feasible for investment indicated by the highest value of benefit-cost ratio (1.54), followed by T3 (1.38), T2 (1.30), and T1 (1.14), respectively. It was suggested that the no-tillage soils covered with rice residues, especially

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in T1, were more economical relative to the tillage soil without any covering in T4 (the control treatment).

Keywords: NK48, no-tillage, rice residue, sink strength index, net profit, benefit-cost ratio

Introduction

Corn (*Zea mays* L.) is one of major economic crops and is an important animal feed crop in Thailand. In the year of 2013 and 2014, the total growing areas are 1,206,632 and 1,201,147 hectares (ha) in animal feed corn production, respectively. The total harvest areas, however, are 1,145,909 and 1,147,430 ha, accounted for 5,062,828 and 5,095,262 tons, with the average yields of 4.41 and 4.43 tons/hectare (t/ha), respectively (Office of Agricultural Economics, 2014). Corn exports will likely decline significantly in the year of 2014–15 as domestic corn prices have increased significantly to around 10–11 baht/kg (USD312-344/ton). The higher corn prices are driven by the shortage of corn in the domestic market as the government still does not allow corn imports to enter Thailand, particularly from Cambodia. The higher prices are, also, mostly due to strong demand from local feed mills (AgroChart, 2014). Increasing corn per unit area and reducing cost of production may eliminate the shortage of corn to meet the raising demand of the buyers. A farm management practice with assuring results of accomplishing this task, such as is no-tillage, should be introduced. However, the no-tillage system is still not well-understood, nor accepted in Thailand. This is most unfortunate and must then be paid attention to; with the use of a no-tillage technique together with a popular hybrid corn genotype like NK48 could give a hope of promoting a better plant growth, increasing crop yield, and reducing inputs as these are the driving factors influencing the farmers' net profits. No-tillage is known by various names include no-till, zero-tillage and direct seeding. Vayuparp and Wongsa (n.d.) reported that the yield of commercial corn hybrids applied with a high plant nutrition at a rate of 87.50 kg N/ha, 43.75 kg P_2O_5/ha and 81.25 kg K_2O/ha revealed that hybrid NK48 corn genotype gave the highest yield (7.80 t/ha) among hybrid corn genotypes. This is the reason why NK48 is becoming a popular corn genotype; thus the selection of this genotype tested in this study. Moschler *et al.* (1972) reported that no-tillage corn production conserves soil and water and reduces capital investment in machinery, but most important to many producers, no-tillage can improve corn yields. No-tillage corn planted into a rye cover crop out-yielded conventional tillage corn by 16 percent (Moschler *et al.* 1972). Zero tillage with 66% soil cover was the best management practice, surpassing the 90% corn yield registered with traditional plow and disk (Martinez-Gamino and Jasso-Chaverria, 2010).

Net economic returns were lower in reduced tillage and no-tillage systems than in mouldboard plough tillage (Malhi *et al*., 1988; Hoffman *et* *al*., 1999). In contrast, net economic return was lower in mouldboard plough tillage than in reduced tillage (Abu-Hamdeh, 2003; Zentner *et al*., 1996). No-tillage cultivation can be effective not only in increasing soil and water conservation, but also by reducing labor requirements and time (Unger and McCalla, 1980). Corn grown under the no-tillage system usually results in higher yields (Na Nagara *et al*., 1984). No-tillage showed a 56% higher average grain yield over the conventional tillage. No-tillage was superior to the conventional tillage in plant growth and development, as expressed in terms of biomass, kernel numbers, and kernel weight (Boonpradub and Welsh, n.d.). Reduced tillage and conventional tillage treatments had the highest grain yield and plant height, respectively (Najafinezhad *et al.*, 2007). Decreasing tillage is very important due to limited time for seedbed preparation and to keep the production cost low (Wilhelm *et al*., 1986; Limon-Ortega *et al*., 2002). Soil compaction in no-tillage soils was not found to be a problem. Saturated hydraulic conductivity measurements suggest better water movement in no-tillage compared with conventional tillage. A review of tillage systems applied in crop production shows that conservation tillage in its many and varied forms holds promise for the sustainability of agricultural productivity and the environment by reducing production costs, preserving soil quality, reducing herbicide and weeding labor input costs and greenhouse gas emissions (Aina, n.d.). Conservation tillage is a practice that leaves at least 30 percent of the soil covered with crop residue (Frazee *et al.*, 2005). There are many variations of conservation tillage systems such as conserving and managing crop residue in combination with no-tillage and mulch-tillage to reduce soil erosion and making animal feed truly sustainable as no-tillage. No-tillage enabled the farmer to sow corn seeds immediately after rice harvest. The potential advantages of using no-tillage include reduced fuel consumption, lower maintenance and repair costs, and lower labor costs (Deen and Kataki, 2003; Lankoski *et al.,* 2004). In addition, Phillips *et al.* (1980) reported that there are just a few of the other possible agricultural benefits of using no-tillage included reduced soil erosion, decreased moisture evaporation and increased land use by allowing farmers to plant on highly erodible or sloping lands. No-tillage can increase a farm’s economic performance through these reductions (Lankoski *et al.*, 2004). Farmers are always looking to adopt cultural management practices that increase yield and decrease input costs. Thus, there is a need to assess growth, yield components, agronomic traits, kernel yield, cost and benefit of NK48 corn genotype grown in no-tillage with the uncut rice ratooncovered with rice straw (T1), no-tillage with the cut rice ratoon covering (T2), no-tillage with the uncut rice ratoon(T3), and tillage without any covering (T4) after rainfed rice harvest hoping that the Thai farmers can have appropriate alternatives to produce more corn with low cost of production, and that can increase their income.

Materials and Methods

Location, Experimental Design, Land Preparation, Planting Method, Fertilizer and Irrigation Application

The study was conducted during the dry season of December, 2010 to May, 2011 at the farmers' fields located in Mae Sai Subdistrict, Rong Kwang district, Phrae province in Thailand. The experiment was laid out in a randomized complete block design (RCBD), replicated 4 times. The farm cultural management practices consisted of: no-tillage with the uncut rice ratoon covered with rice straw (T1), no-tillage with the cut rice ratoon covering (T2), no-tillage with the uncut rice ratoon (T3), and tillage without any covering (T4) occupied the blocks. T4 was used as a control treatment. The NK48 corn genotype was selected and tested in this study. This genotype is an animal feed corn. Each block measured 10 m x 10 m equivalent to 100 m^2 area. The total experimental area was 1,600 m^2. Where the field trial was conducted, the soil was classified as silty soil, with pH of 5.47, organic matter (OM) of 1.14%, phosphorus of 15.00 ppm, and potassium of 190.35 ppm.

Land preparation in the harvested rice fields were not tilled under T1, T2, and T3 except under T4. The 1-meter sharp long sticks were used to make the holes with spacing of 35 cm x 60 cm in all fields of the 4 treatments. Four corn seeds were sown on the holes, 4 seeds/hole or about 53.3 kg corn seeds/ha, then covered by a handful amount of chicken dung per every 3 holes (or 20 g/hole) in each field – T1, T2, T3, and T4. Corn seeds were all sown on the same day in the fields of the 4 treatments (cultural management practices); chicken dung was applied, and considered as basal organic fertilizer.

In T1, corn seeds were sown in the marked holes at the uncut rice ratoon fields, then the dry rice straw weighing 125 gram per 0.36 m^2 (or 3,472 kg/ha) was used to cover the whole field. In T2, corn seeds were sown in the marked holes at the cut rice ratoon fields; residues from the cut rice ratoon were used to cover the whole field. In T3, corn seeds were sown in the marked holes at the uncut rice ratoon fields. In T4, the land was plowed, and then harrowed before corn seeds were sown in the marked holes, just a month after the land harrowing. Fifteen-day old seedlings were thinned and were left at 2 seedlings per hole in each field – T1, T2, T3, and T4. Irrigation was immediately applied after all the activities mentioned above were done.

At 20 days after sowing (DAS), the 15-15-15 chemical fertilizer plus 46-0-0 chemical fertilizer (Urea) were mixed at 1:1 ratio, and then was applied as topdressing fertilizers. The 1st topdressing fertilizer was done at a handful amount per 10 holes (or 156.25 kg/ha). At 40 DAS, the 2nd

topdressing fertilizer was made at the rate of 156.25 kg urea/ha. At 60 DAS, the 3rd topdressing chemical fertilizer was applied at the rate of 93.75 kg urea/ha. Hence, the total organic fertilizer (chicken dung), the total 15-15-15 chemical fertilizer, and the total 46-0-0 (urea) chemical fertilizer applied were 952.38, 78.125 and 328.125 kg/ha, respectively, for each field – T1, T2, T3, and T4.

Irrigation was made with spreading over all the fields for 12 times in total, to keep the soil moist until physiological maturity stage. Weed control was made when it was necessary.

Data Gathered for Plant Growth

At physiological maturity stage, the corn plant samples were taken from the 3 locations (2.1 m^2 per location) in each sowed field – T1, T2, T3, and T4. The area of 2.1 m^2 corresponded to 10 holes (or 20 corn plants). For the dry weight, plant samples were oven-dried at 70°C for 72 hours. Plant growth parameters were determined from these plant samples. The data on plant growth consisted of the following parameters:

Leaf fresh weight, stalk fresh weight, tassel plus peduncle fresh weight, cob fresh weight, husk fresh weight, kernel fresh weight, total plant fresh weight (except root fresh weight due to some difficulty in obtaining its value), leaf dry weight, stalk dry weight, tassel plus peduncle dry weight, cob dry weight, husk dry weight, kernel dry weight, and total plant dry weight. The total plant dry weight was determined by taking the sum of leaf dry weight plus leaf sheath dry weight, stalk dry weight, tassel plus peduncle dry weight, and ear dry weight. Where, ear dry weight composed of cob dry weight, husk dry weight, and kernel dry weight. All of these parameters were measured in a unit of gram per square meter.

Stalk length was measured at the soil surface to the lower node of the peduncle in a unit of centimeter. Tassel plus peduncle length was measured at the upper node of the peduncle to the tip part of the male flower in a unit of centimeter. Plant height is the sum of the stalk length and the tassel plus peduncle length measured in a unit of centimeter. Ear height was measured at the soil surface to the node of growing point of the ear in a unit of centimeter.

Water accumulations in the stalks, leaves, kernels, tassel plus peduncles, cob, and husk were measured and calculated in the unit of gram per square meter. The total plant water accumulation is the sum of the water accumulations in the stalks, leaves, kernels, tassel plus peduncles, cob, and husk, and then it was calculated in the unit of gram per square meter. Then, the percent water accumulation in the stalks, leaves, kernels, cob, husk, tassel plus peduncles, including the percent total plant accumulation were also calculated.

Data Gathered for Yield Components, Agronomic Traits, Kernel Yield, Costs and Benefits

The same plant samples used to determine plant growth were also used to determine the yield components and agronomic traits of the NK48 corn genotype.

Yield components consisted of number of rows per ear, number of kernels per row, and number of kernels per ear was counted. The number of kernels per square meter was also calculated. The dry weight of 400 representative corn kernels was converted to 1,000-kernel dry weight in a unit of gram basis.

Agronomic traits consisted of specific stalk length (SSL), harvest index (HI), and sink strength index (SSI). Specific stalk length is the ratio of stalk length to its stalk dry weight (including leaf sheath dry weight). Harvest index was calculated by dividing the total kernel dry weight by its total dry matter weight (the whole plant dry weight except root dry weight due to some difficulty in obtaining its value). Sink strength index was calculated as the specific stalk length multiplied by ear dry weight. This value was introduced as a way to compare the ability of the plant to partition efficiently its dry matter to the economic part of the plant (i.e., kernels) at physiological maturity which had more efficiency than the value of harvest index.

At physiological maturity stage, kernel yield was taken from the 16.8-m^2 (3.5 m x 4.8 m) crop cut. To obtain the 14% moisture content (MC) of the corn kernels, the threshed kernel samples were oven-dried at 70°C for 72 hours. Subsequently, kernel yield in a unit of kilogram (kg) per 16.8 m^2 was converted into a unit of ton per hectare (t/ha) basis.

The costs and benefits of the NK48 corn genotype were collected and recorded from the 4 different cultural management practices. The gross costs and gross benefits were computed in the unit of baht per hectare per single growing season basis. After that, the benefit-cost ratio (B/C ratio) was also computed as it is the ratio of the gross benefits to the gross costs. Net profit and net loss were computed as the value of gross benefits minus the value of gross costs in the unit of baht per hectare per single growing season.

Data Analysis

Data on plant growth, yield components, kernel yield, and agronomic traits of the NK48 corn genotype was analyzed using the Statistical Analysis System (SAS) software. Means comparisons were done using the Duncan's Multiple Range Test (DMRT). Data on costs and benefits of the NK48 corn genotype derived from the 4 different cultural management practices were completed using Simple Benefit-Cost Analysis.

Results and Discussion

Corn Plant Growth

Leaf fresh weight and stalk fresh weight under T1 (no-tillage with the uncut rice ratoon covered with rice straw) were significantly higher than those under T2 (no-tillage with the cut rice ratoon covering), T3 (no-tillage with the uncut rice ratoon), and T4 (tillage without any covering) (Table 1). No significant difference was noticed in tassel plus peduncle fresh weight under the 4 treatments. T1 gave significantly the highest cob fresh weight, husk fresh weight, and kernel fresh weight followed by T2, T3, and T4, respectively. T1 contributed to having significantly higher total plant fresh weight than the other treatments, mainly due to the high accumulation of leaf fresh weight, stalk fresh weight, cob fresh weight, husk fresh weight, and kernel fresh weight. The total plant fresh weights are positively related to the kernel yields (Tables 1 and 7).

Leaf dry weight, stalk dry weight, tassel plus peduncle dry weight, cob dry weight, husk dry weight, kernel dry weight, and total plant dry weight were significantly different among the 4 treatments (T1, T2, T3, and T4) (Table 2). T1 gave the significantly highest leaf dry weight, while the rest were similar. Stalk dry weight was appreciably heaviest under T1 followed by T2, T3, and T4, respectively. T1 contributed to having the considerably highest tassel plus peduncle dry weight, while its dry weights were similar under the rest of the treatments. The heaviest cob dry weight was found to be in T1 followed by T2, while it was lightest in both T3 and T4. Husk dry weight and kernel dry weight was highest in T1 followed by T2, T3, and T4, respectively. Total plant dry weight (or shoot dry weight) of the corn plants was the highest in T1 followed by T2, T3 and T4, respectively. The lowest total plant dry weight in T4 (tillage without any covering) was due to it had the lowest leaf dry weight, stalk dry weight, cob dry weight, husk dry weight, and kernel dry weight while the highest total plant dry weight in T1 (no-tillage with the uncut rice ratoon covered with rice straw) was mainly due to it had the highest leaf dry weight, stalk dry weight, tassel plus peduncle dry weight, cob dry weight, husk dry weight, and kernel dry weight. These results are in agreement with Wiangsamut *et al.* (2006) who reported that the higher leaf dry weight indicates that more leaves are photosynthetically productive. Later on, assimilates move to the stems. Higher stem dry weight implied more space to accumulate carbohydrates and more green stem areas (non-laminar) to intercept light for photosynthesis producing assimilates for grain filling. Hence, as shoot dry weight increases, grain yield also increases. The results in this study also showed that the total plant dry weights are positively related to the kernel yields (Tables 2 and 7).

Stalk length, tassel plus peduncle length, plant height and ear height for the NK48 corn genotype were very significantly different among the 4 treatments (Table 3). Stalk length was the longest in T1 (no-tillage with the uncut rice ratoon covered with rice straw), the shortest in T4 (tillage without any covering), while stalk length in T2 (no-tillage with the cut rice ratoon covering) and T3 (no-tillage with the uncut rice ratoon) were intermediate between T1 and T4. Plant height was appreciably the tallest in T1 followed by T2, T3, and T4, respectively. Tassel plus peduncle length was significantly the longest in T1, while the rest were similar. Ear height was the tallest in T1 followed by T2, T3, and T4, respectively. Wiangsamut *et al.* (2006) stated that the higher canopy height of the two hybrid genotypes than the three remaining genotypes led to more favorable light penetration and better air circulation lending to higher CO_2 concentration inside the canopy. This was due to the wider space between the leaves of the two hybrid genotypes. Thus, the corn plants grown in no-tillage with the uncut rice ratoon covered with rice straw observed to have the similar results found in our study. These results are in agreement with Abrecht and Bristow (1990) who found that mulching increased the length of the first internode positioning of the apical meristem and increased shoot growth rate before and after emergence. On the other hand, these results disagreed with those of Nesmith *et al.* (1987) and Cassel *et al.* (1995) who stated that shoot development depends on increasing tillage depth would improve the vegetative growth of plants.

There was a very significant difference among the 4 treatments in terms of accumulations of water in the stalks, leaves, kernels, cob, and husk except tassel plus peduncles (Table 4). T1 contributed to having the significantly highest accumulations of water in the stalks, leaves, kernels, cob, and husk, while the accumulations of water in these plant parts were the lowest in T4. The total plant water accumulation differed significantly among the 4 treatments as the plants grown in T1 had significantly higher total plant water accumulation (3,517.1 g/m^2) than those in T2, T3, and T4. The 3 latter treatments had no significant difference in total plant water accumulation ranged from 1,932.8–2,297.8 g/m^2.

The % water accumulation in the stalks, kernels, cob, and husk were not significantly different in the 4 treatments (Table 5). Likewise, no significant difference in % total plant water accumulations were found in the 4 treatments, with values ranged from 57.1–60.6%. The % water accumulation in the leaves differed significantly in the 4 treatments as the plants grown in T1 had the highest % leaf water accumulation but did not differ significantly as compared with that in T2, while both T3 and T4 gave the lowest. Percent (%) water accumulation in the tassel plus peduncles was significantly the highest in T4, but not differed significantly from T3, whereas both T2 and T1 gave the lowest. Overall, the % stalk water accumulations in all the 4 treatments were the highest (33.6–37.8%), followed by the % leaf water accumulations (11.1–13.3%), the % kernel water accumulations (7.2–8.5%), the % cob water accumulations (1.0–1.1%), and the % husk water accumulations (0.1%), respectively.

Corn Yield Components

The number of rows per ear was not significantly different among the 4 cultural management practices, ranging from 12.50–13.00 no/ear (Table 6). The number of kernels per row was significantly higher in T1 than those in T2, T3, and T4. The 3 latter treatments had no significant difference in number of kernels per row. The number of kernels per ear was significantly the highest in T1 followed by T3, T2, and T4, respectively. The number of kernels per square meter was significantly the highest in T3 followed by T2, T4, and T1.

The significantly higher number of kernels per ear and number of kernels per square meter in T3 could not compensate with its significantly lighter 1,000-kernel weight, resulted in a lower kernel yield as compared to that in T2 (Tables 6 and 7). The significantly higher number of kernels per square meter and slightly heavier 1,000-kernel weight in T2 could not compensate with its significantly lower number of kernels per row and significantly lower number of kernels per ear, resulted in a lower kernel yield as compared to that in T1 (Tables 6 and 7). The 1,000-kernel weight in T1 and T2 was significantly heavier than those in T3 and T4. With the 2 latter treatments, 1,000-kernel weight was significantly heavier in T3 than that in T4.

Corn Agronomic Traits

No significant difference in specific stalk length (SSL), sink strength index (SSI), and harvest index (HI) were noticed under the 4 treatments, although those values were not the same (Table 7). The thickest stalk was in T1, the thinnest was in T4, while both T2 and T3 were intermediate between T1 and T4 as indicated by the values of SSL. The thicker stalks usually resulted in the greater total plant dry weight (Tables 7 and 2). Choi and Kwon (1985) reported that bigger tillers usually result in higher leaf area per tiller, hence greater shoot biomass. High assimilate translocated into the ear was observed in T1, followed by T2, while low assimilate translocated into the ear was observed in both T3 and T4 as presented by the values of sink strength index (SSI). This value was used to describe the translocation of assimilates from the source or storage organs or source and storage organs into the ear. Sink strength index value is more applicable than the value of harvest index (HI). These results are in agreement with Wiangsamut *et al.* (2013) who reported that total dry matter accounted for 78.6% yield increase and was positively associated with grain yield. Grain yield under

SL8 and Bigante was higher among the genotypes due to their higher efficiency in partitioning dry matter as measured through sink strength index.

Corn kernel yield

Kernel yield had a very significant difference among the 4 treatments as the plants grown in T1 produced significantly the highest kernel yield (10.37 t/ha), followed by T2 (8.33 t/ha), T3 (7.88 t/ha), and T4 (6.72 t/ha), respectively (Table 7). These results agreed with the findings of Limon-Ortega *et al*. (2002) who reported that retention wheat residue increased kernel yield of corn in summer planting. These results also agreed with Meijer *et al.* (n.d.), who reported that no-tillage is most productive for large-seeded crops like corn and soybean. Corn and soybean yield data from two long-term tillage trials in North Carolina's piedmont confirm how reducing tillage improves yield. Likewise, the results of this study were in agreement with the finding of Thiagalingam *et al.* (1996) who reported that dryland crops of maize, sorghum, soybean and mungbean sown using no-tillage with adequate vegetative mulch on the soil surface produced yields comparable with, or higher than (especially in drier years), those obtained under conventional tillage. The importance of surface mulch in ameliorating soil temperature, moisture and fertility, and in reducing soil movement and loss in crop production in the semi-arid tropics was confirmed. Too little residue or without any covering can result in stunted growth, stress and decreased yields caused from lack of soil water, poor canopy development and high surface temperatures (Doran *et al,*. 1984). Too dense a coverage of crop residues can lead to a cool and moist soil which can delay crop emergence and reduce seed germination, which can affect yields (Halvorson *et al.*, 2006). Too much residue can keep soil temperatures too cool and wet delaying crop emergence; a dense residue cover can also increase weeds and insects and keep herbicides from reaching the soil. So, there seems to be a fine line between not enough and too much residue (Toliver, 2010). Mulch spread on the whole plot increased the grain yield of corn by 60.5% as compared to unmulched control (Bhatt *et al.*, 2004). In our study was found that no-tillage with the uncut rice ratoon covered with rice straw (T1) increased the corn kernel yield by 35.2% as compared to tillage without any covering (T4, the control treatment).

Corn Costs and Benefits

The selling price of kernels was all the same at 10 baht/kg. The gross costs under T1, T2, T3, and T4 were 67,331 baht/ha, 63,630 baht/ha, 56,874 baht/ha, 56,874 baht/ha, 58,677 baht/ha, while the gross benefits were 103,700, 83,300, 78,800, and 67,200, respectively (Table 8). The highest net profit was under T1 (36, 369 baht/ha), followed by T3 (21, 926 baht/ha), T2 (19, 670 baht/ha), and T4 (8, 523 baht/ha), respectively. The highest cost of production under T1 could compensate with the highest benefit, resulting in the highest net profit (36, 369 baht/ha) due to the significantly highest kernel yield (10.37 t/ha). The lowest net profit (8,523 t/ha) under T4 was mainly due to the high cost of production (especially, plowing and harrowing the growing areas) and the lowest kernel yield (6.72 t/ha). These results are in agreement with Murdock *et al.* (n.d.), who reported that no-tillage system have a favorable effect on the corn and soybean crops grown in rotation with the no-till wheat as no-till wheat was grown, the average yields of no-till corn and soybeans had 4.2% and 5.8% greater yields, respectively, than when these crops were grown after tilled wheat. This increase in yield results in about the USD79/ha increases in profits for the 2-year rotation of wheat, double-cropped soybeans and corn (Murdock *et al.*, n.d.). The similar results were found from Buman *et al.* (2004) who reported that yield differences among tillage systems within years were not significant for either crop, but profit for no-tillage and strip-tillage corn was the highest in four of its five years. While the five-year average profit for soybean was also the highest for the no-tillage, narrow-row system. Rotating corn and soybean using no-tillage systems resulted in USD130 to USD145/ha more profit than the other practices (Buman *et al.*, 2004). Based on the results of this study, the production of the NK48 corn genotype under T1 was the most feasible for investment indicated by the highest value of benefit-cost ratio (1.54), followed by T3 (1.38), T2 (1.30), and T1 (1.14), respectively (Table 8). Tongaram (2004) and Bangchaud (2001) stated that most of investors would select a project that could gain the net profits in the shortest period based on the value of B/C ratio. The value of B/C ratio determines the feasibility of the investment: more than 1 could mean that the project is more feasible; equal to 1 could mean that the project is still feasible; whereas the value that is less than 1 could mean that it is not feasible for investment because of a possible loss.

Table 1. Leaf fresh weight, stalk fresh weight, tassel plus peduncle fresh weight, cob fresh weight, husk fresh weight, kernel fresh weight, and total plant fresh weight (g/m^2).

Cultural management practice	Leaf fresh weight (g/m^2)	Stalk fresh weight (g/m^2)	Tassel plus peduncle fresh weight (g/m^2)	Cob fresh weight (g/m^2)	Husk fresh weight (g/m^2)	Kernel fresh weight (g/m^2)	Total plant fresh weight (g/m^2)
No-tillage with the uncut rice ratooncovered with rice straws(T1)	1,079.1a	2,788.4a	141.0a	286.6a	191.3a	1,302.5a	5,788.9a
No-tillage with cut rice ratoon covering(T2)	736.1b	1,769.3b	120.4a	198.2b	140.3b	1,046.2b	4,010.5b
No-tillage with uncut rice ratoon(T3)	613.8b	1,638.8b	115.3a	177.0c	131.6c	989.7c	3,666.3b
Tillage without any covering(T4)	528.4b	1,446.2b	125.4a	175.6c	115.1d	843.2d	3,234.0b
CV (%)	13.64	18.04	16.06	0.76	1.28	0.22	10.86

Means of parameters for each column with the same letter are not significant difference at the 0.01 probability level using DMRT for comparison

Table 2. Leaf dry weight, stalk dry weight, tassel plus peduncle dry weight, cob dry weight, husk dry weight, kernel dry weight, and total plant dry weight (g/m^2).

Cultural management practice	Leaf dry weight (g/m^2)	Stalk dry Weight (g/m^2)	Tassel plus peduncle dry weight (g/m^2)	Cob dry weight (g/m^2)	Husk dry weight (g/m^2)	Kernel dry weight (g/m^2)	Total plant dry weight (g/m^2)
No-tillage with the uncut rice ratoon covered with rice straws(T1)	312.4a	584.3a	68.4a	229.2a	185.6a	891.9a	2271.81a
No-tillage with the cut rice ratoon covering(T2)	229.9ab	414.8b	56.6a	158.6b	136.1b	716.6b	1712.61b
No-tillage with the uncut rice ratoon(T3)	206.2ab	371.1bc	41.9a	141.6c	127.6c	677.9c	1566.30b
Tillage without any covering(T4)	164.6b	263.7c	43.1a	140.5c	111.7d	577.6d	1301.18c
CV (%)	20.33	15.70	30.61	0.77	1.29	0.22	6.70

Means of parameters for each column with the same letter are not significant difference at the 0.01 probability level using DMRT for comparison

Table 3. Stalk length, tassel plus peduncle length, plant height, and ear height (centimeter (cm)).

Cultural management practice	Stalk length (cm)	Tassel plus peduncle length (cm)	Plant height (cm)	Ear height (cm)
No-tillage with the uncut rice ratoon covered with rice straws(T1)	215.00a	51.47a	320.22a	111.00a
No-tillage with the cut rice ratoon covering(T2)	175.13b	46.03b	264.94b	84.50b
No-tillage with the uncut rice ratoon(T3)	159.50b	50.28ab	249.66bc	74.25c
Tillage without any covering(T4)	130.00c	50.81ab	213.31c	45.00d
CV (%)	6.15	4.28	7.90	3.83

Means of parameters for each column with the same letter are not significant difference at the 0.01 probability level using DMRT for comparison

Table 4. Water accumulations in the stalks, leaves, kernels, tassels plus peduncles, cobs, husks, and total plants in a unit of gram per square meter (g/m^2).

Cultural management practice	Stalk water accumulation (g/m^2)	Leaf water accumulation (g/m^2)	Kernel water accumulation (g/m^2)	Tassel plus peduncles water accumulation (g/m^2)	Cob water accumulation (g/m^2)	Husk water accumulation (g/m^2)	Total plant water accumulation (g/m^2)
No-tillage with the uncut rice ratoon covered with rice straws(T1)	2,204.1a	766.7a	410.6a	72.6a	57.3a	5.7a	3,517.1a
No-tillage with the cut rice ratoon covering(T2)	1,354.5b	506.1b	329.6b	63.7a	39.6b	4.2b	2,297.8b
No-tillage with the uncut rice ratoon(T3)	1,267.7b	407.6b	311.9c	73.5a	35.4c	3.9c	2,100.0b
Tillage without any covering(T4)	1,182.5b	363.8b	265.6d	82.4a	35.1c	3.5d	1,932.8b
CV (%)	21.25	12.97	0.21	17.76	0.78	1.39	15.31

Means of parameters for each column with the same letter are not significant difference at the 0.01 probability level using DMRT for comparison

Table 5. Percent water accumulations in the stalks, leaves, kernels, cobs, husks, tassels plus peduncles, and total plants in a unit of percent (%).

Cultural management practice	Stalk water accumulation (%)	Leaf water accumulation (%)	Kernel water accumulation (%)	Cob water accumulation (%)	Husk water accumulation (%)	Tassel plus peduncles water accumulation (%)	Total plant water accumulation (%)
No-tillage with the uncut rice ratoon covered with rice straws(T1)	37.8a	13.3a	7.2a	1.0a	0.1a	1.3c	60.6a
No-tillage with the cut rice ratoon covering(T2)	33.6a	12.6ab	8.3a	1.0a	0.1a	1.6bc	57.1a
No-tillage with the uncut rice ratoon(T3)	34.5a	11.1b	8.5a	1.0a	0.1a	2.0ab	57.2a
Tillage without any covering(T4)	36.4a	11.2b	8.3a	1.1a	0.1a	2.5a	59.6a
CV (%)	10.08	7.41	9.87	9.85	9.07	17.44	5.34

Means of parameters for each column with the same letter are not significant difference at the 0.01 probability level using DMRT for comparison

Table 6. Number of rows per ear, number of kernels per row, number of kernels per ear, number of kernel per square meter, and 1,000-kernel weight.

Cultural management practice	Number of rows per ear (no/ear)	Number of kernels per row (no/row)	Number of kernels per ear (no/ear)	Number of kernel per square meter (no/m^2)	1,000-kernel weight (g) MC14.5%
No-tillage with the uncut rice ratoon covered with rice straws(T1)	13.00a	28.4a	366.75a	2,492.9d	297.0a
No-tillage with the cut rice ratoon covering(T2)	12.50a	23.3b	290.25c	2,764.3b	301.5a
No-tillage with the uncut rice ratoon(T3)	13.00a	24.0b	309.96b	2,952.0a	267.0b
Tillage without any covering(T4)	12.50a	22.3b	277.83d	2,646.0c	253.9c
CV (%)	7.84	7.56	1.37	1.37	1.56

Means of parameters for each column with the same letter are not significant difference at the 0.01 probability level using DMRT for comparison

Table 7. Kernel yield, specific stalk length, sink strength index, and harvest index.

Cultural management practice	Specific stalk length (cm/g)	Sink strength index (SSI) (cm)	Harvest index (HI)	Kernel yield (t/ha)
No-tillage with the uncut rice ratoon covered with rice straws(T1)	3.54a	486.2a	0.44a	10.37a
No-tillage with the cut rice ratoon covering(T2)	4.19a	444.9a	0.47a	8.33b
No-tillage with the uncut rice ratoon(T3)	4.11a	408.5a	0.48a	7.88c
Tillage without any covering(T4)	4.80a	418.4a	0.50a	6.72d
CV (%)	16.19	15.31	5.21	0.30

Means of parameters for each column with the same letter are not significant difference at the 0.01 probability level using DMRT for comparison

Table 8. Simple benefits and costs (production economics) of the NK48 corn genotype grown in tillage and non-tillage soils with different rice residue management practices.

Item	Cost/unit	Unit number	Total (baht/hectare/single growing season) for each cultural management practice			
			No-tillage with the uncut rice ratooncovered with rice straws(T1)	No-tillage with cut rice ratoon covering(T2)	No-tillage with uncut rice ratoon(T3)	Tillage without any covering(T4)
1. Taxes of the land	44 baht/hectare (ha)/year (1 year = 2 cropping)	1 cropping (dry season)/ha	22	22	22	22
2. Seed price for NK48 corn genotype	150 baht/kg	53.3 kg/ha	7,995	7,995	7,995	7,995
3. Plowing (inclusive of meal)	1,875 baht/ha	1 time/ha	-	-	-	1,875
4. Harrowing (inclusive of meal)	1,875 baht/ha	1 time/ha	-	-	-	1,875
5. Seed drilling and basal fertilizer applied	300 baht/man-day	20 man-day/ha	6,000	6,000	6,000	6,000
6. Dry rice straw	1 baht/kg	3,472 kg	3,472	-	-	-
7. Rice straw transportation	576 baht/ton of rice straw	3.472 tons of rice straw/ha	2,000	-	-	-

Table 8. Continued

Item	Cost/unit	Unit number	Total (baht/hectare/single growing season) for each cultural management practice			
			No-tillage with the uncut rice ratooncovered with rice straws(T1)	No-tillage with cut rice ratoon covering(T2)	No-tillage with uncut rice ratoon(T3)	Tillage without any covering(T4)
8. Labour for transferring and spreading the dry rice straw	300 baht/man-day	5 man-days	1,500	-	-	-
9. Labour for cutting the rice ratoon	300 baht/man-day	20 man-day/ha	-	6,000	-	-
10. Pump rental (5% of gross yield)	-	***	5,185	4,165	3,940	3,360
11. Diesel for irrigation	2hrs/time/day x 12 times/ha x 3.25 liter diesel/2 hrs/time x 31 baht/liter diesel	39 liters diesel/ha	1,209	1,209	1,209	1,209
12. Laborer for irrigation	150 baht/man-day	12 days x 2 man-days/ha	3,600	3,600	3,600	3,600
13. Chicken dung as basal organic fertilizer	4 baht/kg	952.38 kg	3,808	3,808	3,808	3,808
14. Chemical fertilizer (15-15-15)	1,150 baht/sack (50 kg/sack)	78.125 kg/ha	1,797	1,797	1,797	1,797
15. Urea [CO(NH2)2] (46-0-0)	1,250 baht/sack (50 kg/sack)	328.125 kg/ha	8,203	8,203	8,203	8,203
16. First topdressing fertilizer	300 baht/man-day	3 man-days	900	900	900	900

Table 8. Continued

Item	Cost/unit	Unit number	Total (baht/hectare/single growing season) for each cultural management practice			
			No-tillage with the uncut rice ratooncovered with rice straws(T1)	No-tillage with cut rice ratoon covering(T2)	No-tillage with uncut rice ratoon(T3)	Tillage without any covering(T4)
17. Second topdressing fertilizer	300 baht/man-day	3 man-days	900	900	900	900
18.Third topdressing fertilizer	300 baht/man-day	3 man-days	900	900	900	900
19. Herbicide (weed killer)	350 baht/liter of chemical	2-4 liter of chemical/ha	700	1,400	1,400	1,400
20. Herbicide spraying	300 baht/man-day	3 man-days/ha	900	900	900	900
21. Harvesting (exclusive of meal)	300 baht/man-day	20 man-day/ha	6,000	6,000	6,000	6,000
22. Sacks	135-208 sacks/ha	5 bath/sack	1,040	835	790	675
23. Corn threshing (exclusive of meal)	500 baht/ton	***	5,185	4,165	3,940	3,360
24. Packaging (sack cost)	5 baht/sack (50 kg/sack)	***	1,037	833	788	672
25. Transportation of the kernels from farm to house	10 baht/sack of corn kernels (50kg/sack)	***	2,074	1,666	1,576	1,344
26. First kernel drying	7 baht/sack of corn kernels (50 kg/sack)	***	1,452	1,166	1,103	941
27. Second kernel drying	7 baht/sack of corn kernels	***	1,452	1,166	1,103	941
Gross costs/ha basis (1)	-	-	67,331	63,630	56,874	58,677
Gross benefits/ha basis (2)	10 baht/kg of kernels at 14%MC	***	103,700	83,300	78,800	67,200
Net profit or net loss/ha basis = (2) – (1)	-	-	36,369	19,670	21,926	8,523
Benefit/Cost ratio = (2) ÷ (1)	-	-	1.54	1.30	1.38	1.14

*** Gross kernel yields of NK48 corn genotype at 14%MC in T1, T2, T3, and T4 were 10.37, 8.33, 7.88 and 6.72 t/ha, respectively. Baht is a Thai currency. Where; the 31.98 baht is equivalent to 1 USD on July 31, 2014 (X-rates. 2014).

Conclusions

The significantly highest total plant dry weight in T1 (no-tillage with the uncut rice ratoon covered with rice straws) was attributed to leaf dry weight, stalk dry weight, tassel plus peduncle dry weight, cob dry weight, husk dry weight, and kernel dry weight compared to the rest of treatments. Plant growth under T1 was better than those under T2 (no-tillage with the cut rice ratoon covering), T3 (no-tillage with the uncut rice ratoon), and T4 (tillage without any covering) in terms of stalk length, tassel plus peduncle length, plant height, and ear height. The amount of the total plant water accumulation in T1 was significantly higher than those in T2, T3, and T4 mainly due to its greater water accumulation in all the stalks, leaves, kernels, cobs, and husks. The % total plant water accumulation was similar in all the 4 cultural management practices (T1, T2, T3, and T4) ranging from 57.1–60.6%. Overall, the % water accumulation in the stalks in all the 4 cultural management practices was the highest, followed by the % leaf water accumulation, the % kernel water accumulation, the % cob water accumulation, and the % husk water accumulation, respectively. The significantly highest kernel yield was found in T1 mainly due to the more number of kernels per row and number of kernels per ear, and heavy 1,000-kernel weight. Sink strength index (SSI) is more an applicable value being used to describe the translocation of assimilates from the source or storage organs or source and storage organs into the ear than harvest index (HI) value.

The gross costs under T1, T2, T3, and T4 were 67,331 baht/ha, 63,630 baht/ha, 56,874 baht/ha, 56,874 baht/ha, and 58,677 baht/ha, while the gross benefits were 103,700, 83,300, 78,800, and 67,200, respectively. The highest net profit was under T1 (36,369 baht/ha), followed by T3 (21,926 baht/ha), T2 (19,670 baht/ha), and T4 (8,523 baht/ha), respectively. The highest cost of production under T1 could compensate with the highest benefit, resulting in the highest net profit (36,369 baht/ha) due to the significantly highest kernel yield (10.37 t/ha). The lowest net profit (8,523 baht/ha) under T4 was mainly due to the high cost of production and the lowest kernel yield (6.72 t/ha). Therefore, yields are one of the most important factors influencing profit. Low yields usually translate into lower profits (or losing money) whereas high yields usually mean higher profits. The production of the NK48 corn genotype under T1 was the most feasible for investment as found in this study, indicated by the highest value of benefit-cost ratio (1.54), followed by T3 (1.38), T2 (1.30), and T1 (1.14), respectively. It was suggested that the no-tillage soils covered with rice residues, especially in T1, were more economical relative to the tillage soil without any covering in T4 (the control treatment).

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