Chapter 3

Responses to gall midge of Muey Nawng in farmer's rice field

3.1 Introduction

The previous study (Chapter 2) confirmed that the rice gall midge is a serious insect pest of rice at Mae Moot village. In general, the rice gall midge is known to cause losses of rice yield (Hidaka *et al.*, 1974). However, I found that the local rice variety "Muey Nawng" exhibited very little silver shoots symptom, typical of gall midge damage, although similar number of the insect were collected over it did not differ from other rice varieties. Farmers in the village, along with farmers in other areas of northern Thailand, also say that this is the rice variety they grow to overcome gall midge problem. Throughout the provinces of northern Thailand, from Chiang Mai, Phrae, Nan to Mae Hong Son, the seed of Muey Nawng is maintained by farmers who are skilled in seed selection (Supamongkol, 2006). It is well known that different of local crop varieties can be given the same name and different names can be applied to the same varieties (Harlan, 1992). Genetic variation has been found in different accessions of local rice varieties with the same name (Meesin, 2003). Farmers' accessions of Muey Nawng from northern Thailand were found to share some common characteristics, such as tall plant type with bold, glutinous grain inside mainly straw colored husk (Supamongkol, 2006). The author, however, also found differences in adaptation, for example, when grown together at Chiang Mai University flowering were up to 30 days apart. Genetic variation in local rice varieties is important for the maintenance stable yield pattern (Zeven, 1999). It has been pointed out that tolerance or resistant to insect pests in the rice varieties may also vary in the defense mechanism to the insect's attack in different rice varieties (Omoloye *et al*., 2002). Pathak and Saxena (1976) suggested that the tolerance may be in the form of ability repair damage and recovery from injury without any yield loss The purposes of this study were (a) to examine relate yield loss of farmer's rice varieties to the degree of gall midge infestation and (b) to determine variation among twenty farmer's accessions of Muey Nawng from different locations in their response to gall midge under farmer's field condition. In addition, the tolerance indicators in some Muey Nawng accessions and popular improve varieties to highly gall midge presence and gall midge absence were determined.

3.2 Materials and Method

3.2.1 Determination of gall midge damage in popular rice varieties in farmer's rice field

The field experiment was carried out at Mae Moot village, Mae Win sub district, Mae Wang district, Chiang Mai province in the 2004 wet season. The experiment was determined the gall midge damage in four popular farmer's rice varieties as in Experiment 2.2.2, with treatments arranged in a randomized complete block design. One month old seedlings were transplanted in four replications at spacing of 0.25 X 0.25 m, one seedling hill^{-1}, in 3 m X 4 m plots. Fertilizers were applied at the rate of 50 kg N ha^{-1} and 31.25 kg P_2O_2 ha^{-1} at 4 weeks after transplanting and 50 kg N ha^{-1} at heading stage. Hand weeding was done at 3 weeks after transplanting and pre-heading stage before the second fertilizer application.

Number of silver shoots and normal tillers $hill^{-1}$ were determined on 20 random hills within the interior of each plot, at 60, 80 day after transplanting and heading stage. The percentage of infestation was calculated in the same way as in experiment 2.2.2. At maturity stage, samples were taken in 1 x 1 m^{-2} internal area of each plot and cut at ground level, for determination of non-productive tillers $hill^{-1}$, normal tillers $hill^{-1}$, panicles $hill^{-1}$ and plant height (measured to collar of the panicle). After threshing, the weight of filled and unfilled grain and straw were measured. The grain was evaluated for moisture content by grain moisture tester (Kett Electric Laborator, Rice tester M999) and converted to 14 % grain moisture content. Straw was oven dried at 75 ºC for 48 hours before weighing.

Data were analyzed using analysis of variance (ANOVA) to determine the effects of variety. Mean were compared by least significant different (LSD) at $P<0.05$. All of statistical analyses were done by using commercial software (Statistix V. 8, Analytical Software, Inc.). The data in percentages were transformed by arcsine before statistic analysis.

3.2.2 Variation in gall midge resistance among Muey Nawng accession: field evaluation

The twenty accessions of Muey Nawng were collected from different farmers in three provinces in Northern Thailand: Chiang Mai, Nan, Mae Hong Son (Table 3.1). This experiment evaluated the twenty accessions of Muey Nawng to gall midge infestation in farmer's field at Mae Moot village, Mae Wing sub district, Mae Wang district, Chiang Mai province in 2004 wet season. Check varieties included RD4 and Muey Nawng 62M (gall midge resistant) and San-pah-tawng1 (gall midge susceptible). One month old seedlings of the 3 accessions of Muey Nawng and 3 check varieties were transplanted at one seedling hill^{-1} in four replications. Each plot was two rows of 12 plants and with 0.25 x 0.25 m spacing. Fertilizer application and weed control were done in the same way as Experiment 3.2.1.

The silver shoots and normal tillers hill^{-1} were counted on 10 random hills within the middle of each two row, at 60, 80 days after transplanting and heading stage. Gall midge damage was assessed in the same way as in Experiment 2.2.2. At maturity stage, samples were taken from 5 hills in the middle of each row (10 hills per plot) and cut at ground level. Number of non-productive tillers hill^{-1}, normal tillers hill^{-1}, panicles hill^{-1} and plant height (from ground level of panicle collar) were determined. After threshing the grain and straw were weighed separately. Moisture content of the grain was measured with grain moisture tester (Kett Electric Laborator, Rice tester M999) and converted to 14 % grain moisture content. Straw was oven dried at 75 ºC for 48 hours before weighing. For statistic analysis, data were analyzed using the mean of four replicates ± SE.

Table3.1 The 20 accessions of glutinous grain type of Muey Nawng collected from farmers in three provinces in Northern Thailand.

Accession (MN)	Province
1	Chiang Mai
2	Nan
3	Mae Hong Son
4	Chiang Mai
5	Chiang Mai
6	Nan
7	Nan
8	Chiang Mai
9	Nan
10	Chiang Mai
11	Nan
12	Chiang Mai
13	Nan
14	Chiang Mai
15	Nan
16	Chiang Mai
17	Chiang Mai
18	Chiang Mai
19	Chiang Mai
20	Chiang Mai

3.2.3 Comparing accessions of Muey Nawng with different gall midge resistance and improved rice varieties in environments with different gall midge damage.

Two gall midge resistant Muey Nawng accessions (MN1 and MN6), one moderately resistant (MN20) and two susceptible accessions (MN8 and MN9) identified in Experiment 3.2.2 and three checks (KDML105, RD6 (susceptible varieties) and Muey Nawng 62 M (resistant variety)) were evaluated in one location with gall midge problem (MM, Mae Moot village, Mae Win sub district, Mae Wang district, Chiang Mai) and one without the gall midge problem (CMU, Multiple

Cropping Center, Faculty of Agriculture, Chiang Mai University) in the wet season of 2005. At both locations, one month old seedlings of the rice varieties were transplanted at one plant hill^{-1}, with 0.25 x 0.25 m spacing in 2 x 4 m. plots, with four replications in a completely randomized block. The transplanting time coincided with the tillering stage of most farmers' rice varieties at Mae Moot village. The transplanting was done at CMU 15 days after that, which was about the same time of rice transplanting at lower altitudes in Chiang Mai Valley, about two days later than at Mae Moot. At Mae Moot a system of lighting was set at the center of each plot for increase of the number of gall midge (as in Experiment 2.2.1) but at Chiang Mai University there was no lighting. Fertilizer and weed management were done as in Experiment 3.2.1.

The number of silver shoots and normal tillers hill^{-1} were assessed on 28 hills within the interior of each plot, at 60 and 80 days after transplanting. The percentage of gall midge infestation was calculated as in Experiment 2.2.2. At maturity stage, samples of five accessions of Muey Nawng and three check varieties were taken in the same 28 hills that were gall midge infestation, cutting at ground level. The number of non-productive tillers hill^{-1}, normal tillers hill^{-1} and panicle hill^{-1} were determined. After threshing grain, unfilled grain and straw were weighed separately. Grain moisture was measured with a grain moisture tester (Kett Electric Laborator, Rice tester M999) and grain weight was converted to 14 % grain moisture content. Straw was oven dried at 75 ^{o}C for 48 hours before weighing.

Data were analyzed using analysis variance (ANOVA) to determine the effects of variety. Mean were compared by least significant different (LSD) at $P<0.05$. All of statistical analyses were done by using commercial software (Statistix V. 8, Analytical Software, Inc.). Data in percentages were arcsine-transformed for statistic analysis.

3.3 Results

3.3.1 Determine of gall midge damage in popular rice varieties in farmer's field.

At vegetative stage

The number of normal tillers hill^{-1} varied in the 4 rice varieties and in stages of rice plant (Table 3.2). At 60 days after transplanting, the normal tillers hill^{-1} was the highest in Phrae 1, intermediate in Muey Nawng and RD6, and lowest in Nahng Gao. After that, Muey Nawng and Phrae 1 had the higher the normal tillers hill^{-1} than RD6 but the normal tillers hill^{-1} was not different among in Phrae 1 and RD6 or in RD6 and Nahng Gao at 80 days after transplanting. At heading stage, the normal tiller hill^{-1} was the highest in Phrae 1 and lowest in Nahng Goa. Therefore, it was same among in Muey Nawng and RD6.

The percentage of infestation by rice gall midge was found to differ among different rice varieties and in stages of rice plant (Table 3.3). At 60 day after transplanting, gall infestation was low, but with some notable difference among the varieties (Table 3.3). RD6 had the highest percentage of infestation at 4%, followed by Nahng Gao at 0.6% and Phrae 1 at 0.2%, while Muey Nawng was completely free of gall midge damage. By 80 days after transplanting, the percentage of infestation increased in all varieties, and was highest in RD6 at 30.1%, followed by Nahng Gao at 23.8%, Phare 1 at 5.0%, and only 1.1% in Muey Nawng. At heading stage, the percentage of infestation had declined in all varieties. There was no gall midge infestation in Meuy Nawng and only very few at about 0.3-0.4% in the other varieties.

At maturity stage

The number of normal tillers hill^{-1} was higher in Phrae 1 and RD6 than in Muey Nawng and Nahng Gao (Table 3.4). In addition, the number of panicles hill^{-1} was the highest in Phrae 1 followed by RD6, Muey Nawng and Nahng Gao with 11.3, 8.5, 7.7 and 5.6 panicles hill^{-1}, respectively. However, the number of unproductive tillers hill^{-1} was higher in RD6 and Nahng Gao than in Muey Nawng and Phrae 1. In addition, RD6 and Nahng Gao had especially high number of unproductive tillers. Only 70% of their tillers developed into panicles compared with almost all of the tillers that developed in panicles in Muey Nawng and Phrae 1. Nahng Gao with plant height of 174 cm and Muey Nawng at 160 cm were tall plant type (Table 3.5). RD6, although an improved variety, is also of the tall plant height, with 146 cm, where as Phrae 1 is a semi-dwarf, with only 94 cm. Meuy Nawng had the highest the straw dry weight and grain yield than other varieties. The straw dry weight was 1,060, 661, 706 and 769 g m^{-2} in Muey Nawng, Phrae 1, RD6 and Nahng Gao, respectively. While the grain yield was 653.9, 434.1, 492.1 and 509.6 g m^{-2} in Muey Nawng, Phrae1, RD6 and Nahng Gao, respectively. The percentage of unfilled grain (by weight) at almost 10% in RD6 and Nahng Gao were more than twice that in Muey Nawng and Phrae 1.

Table 3.2 Number of normal tillers in four rice varieties at different stages of growth in farmer's field at Mae Moot village.

Variety	60 days after transplanting	80 days after transplanting	heading stage
		(normal tillers hill^{-1})	
Muey Nawng	10.9 B	12.7 A	8.1 BC
Phrae 1	14.9 A	12.1 AB	11.8 A
RD6	11.5 B	9.7 BC	9.7 B
Nahng Gao	8.5 C	8.0 C	7.3 C
F-test	*	*	*

*=significant at *P*<0.05. NS=not significant at P<0.05. Difference between varieties in the same column is indicated by different upper case letters.

Table 3.3 Gall midge infestation (%) in four rice varieties at different stages of growth in farmer's field at Mae Moot village.

Variety	60 days after transplanting	80 days after transplanting	heading stage
		(%)	
Muey Nawng	0 B	1.1 D	0 C
Phrae 1	0.2 B	5.0 C	0.3 B
RD6	4.1 A	30.1 A	0.4 A
Nahng Gao	0.6 AB	23.8 B	0.3 B
F-test	*	*	*

Data were arcsine-transformed percentage for statistic analysis.

*=significant at *P*<0.05. Difference between varieties in the same column is indicated by different upper case letters.

Table 3.4 Number of normal tillers, panicles and unproductive tillers in four rice varieties at maturity stage in farmer's field at Mae Moot village.

Variety	Normal tillers hill^{-1}	Panicles hill^{-1}	Unproductive tillers hill^{-1}
Muey Nawng	8.0 B	7.7 B	0.3 B
Phrae 1	11.5 A	11.3 A	0.2 B
RD6	12.1 A	8.5 B	3.6 A
Nahng Gao	8.2 B	5.6 C	2.6 A
F-test	*	*	*

*=significant at *P*<0.05. Difference between varieties in the same column is indicated by different upper case letters.

Table 3.5 Plant height, straw dry weight, grain yield (at 14 % grain moisture content) and unfilled grain in four rice varieties at maturity stage in farmer's field at Mae Moot village.

Variety	Plant height (cm)	Straw dry weight (g m^{-2})	Grain yield (g m^{-2})	Unfilled grain (g m^{-2})
Muey Nawng	160.2 B	1,060 A	653.9 A	20.5 B
Phrae 1	93.6 D	661 B	434.1 B	18.8 B
RD6	146.0 C	706 B	492.1 B	43.8 A
Nahng Gao	173.6 A	769 B	509.6 B	38.5 A
F-test	*	*	*	*

*=significant at *P*<0.05. Difference between varieties in the same column is indicated by different upper case letters.

3.3.2 Evaluation of twenty accessions of Muey Nawng to infestation of gall midge in field condition.

Vegetative growth

The number of normal tillers hill^{-1} varied significantly among the Muey Nawng accessions in all three stages of growth (Figure 3.1). Most of the Muey Nawng accessions, Muey Nawng 62 M and RD4 had the highest number of normal tillers hill^{-1} at 60 days after transplanting. After that, the number of tillers hill^{-1} declined in most Muey Nawng accessions at 80 days after transplanting and then stayed about the same heading stage. But MN4, MN8 and MN20 had similarly the normal tiller hill^{-1} at 3. Moreover, MN6, MN7 and MN11 had similar number of normal tiller hill^{-1} at 60 and 80 days after transplanting, but with fewer normal tiller hill^{-1} at heading stage. In contrast, the normal tillers hill^{-1} in San-pah-tawng 1 (susceptible variety) was the highest at 60 days after transplanting, then fewer at 80 days after transplanting and even fewer at heading stage. The number of normal tillers hill^{-1}was higher in San-pah-tawng1 than all Muey Nawng accessions and two resistance checks (Muey Nawng 62 M and RD4) at three stages of rice. Moreover, most of Muey Nawng accessions had similarly the normal tillers hill^{-1} in Muey Nawng 62M and RD4 at 3 stages of rice.

There was a great deal of variation in percentages of infestation by rice gall midge among the Muey Nawng accessions, and over the three times of examination (Figure 3.2). Several accessions of Muey Nawng (MN3, MN5, MN6 and MN18), along with Muey Nawng 62 M and RD4 showed no or hardly any damage by gall midge. For those Muey Nawng accessions that showed gall midge infestation, the highest percentage of infestation was at 80 days from transplanting, with much lower infestation at 60 days or at heading. San-pah-tawng 1 showed only 5 % infestation at 60 days after transplanting, after that it's infestation remained very high from 80 days to heading.

At maturity stage

The number of normal tillers of the twenty Muey Nawng accessions ranged from 6.8 to 9.2 normal tillers hill^{-1} (Figure 3.3). The RD4 and SPT1 had more tillers hill^{-1} than in all of Muey Naewng accessions and Muey Nawng 62M. Most of Muey Nawng accessions had similarly the normal tillers hill^{-1} with Muey Nawng 62M.

The twenty Muey Nawng accessions ranged from 5.8 to 8.6 panicles hill^{-1}, which was in the same range as the check varieties Muey Nawng 62 and San-pah-tawng 1 (Figure 3.4). The other check variety, RD4, had almost twice as many panicles.

The number of unproductive tillers hill^{-1} of Muey Nawng accessions ranged 0.3-1.7 unproductive tillers hill^{-1}, with RD4 and Muey Nawng 62M within this same range (Figure 3.5). San-pah-tawng 1, however, had more than 6 unproductive tillers hill^{-1}.

The grain yield (at 14% moisture content) of Muey Nawng accessions varied from 526 to 806 g m^{-2} (Figure 3.6). San-pah-tawng 1 yielded less than one third of the lowest yielding Muey Nawng accessions, whereas the grain yield of Muey Nawng 62M was in the same range as the higher yielding of the Muey Nawng accessions.

The unfilled grain of Muey Nawng accessions ranged from 14.1 to 34.6 g m^{-2}, with Muey Nawng 62M at the high end of this range (Figure 3.6). San-pah-tawmg1 had twice to five times as much, by weight, of unfilled grain.

The straw dry weight of Muey Nawng accessions ranged from 616 to 931g m^{-2}, with Muey Nawng 62M in this range (Figure 3.7). Straw dry weight was significantly lower in San-pah-tawng1 and even lower in RD4

The plant height of Muey Nawng accessions ranged from 133 to 141 cm, with Muey Nawng 62M in this range (Figure 3.8). RD4 and San-pah-tawng 1, which semi-dwarf varieties, were only 81-82 cm in height.

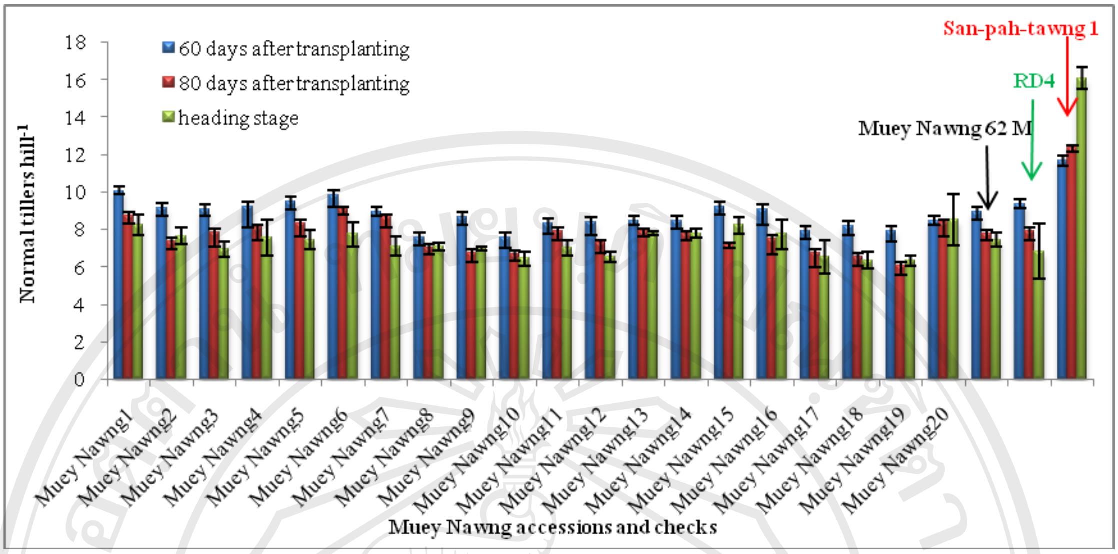

Figure 3.1 Number of normal tillers in 20 Muey Nawng accessions and three check varieties (Muey Nawng 62 M, RD4 (resistant) and San-pah-tawng 1 (susceptible) at three different growth stages in farmer's field at Mae Moot village, Error bars represent ± SE (n=4).

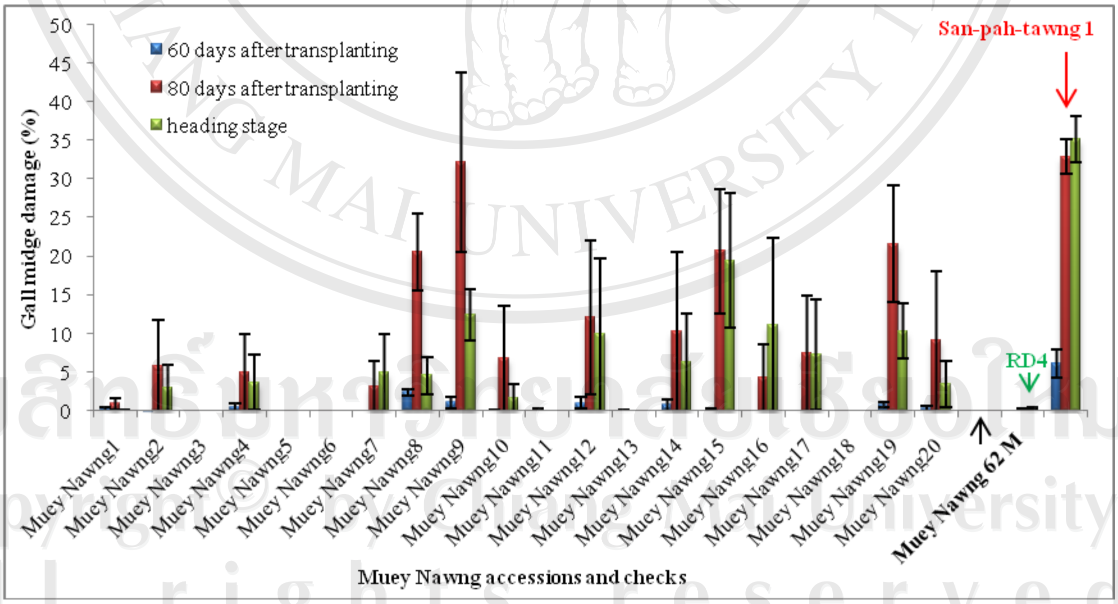

Figure 3.2 Gall midge infestation (%) in 20 Muey Nawng accessions and three check varieties (Muey Nawng 62 M, RD4 (resistant) and San-pah-tawng 1 (susceptible) at three different growth stages in farmer's field at Mae Moot village, Error bars represent ± SE (n=4).

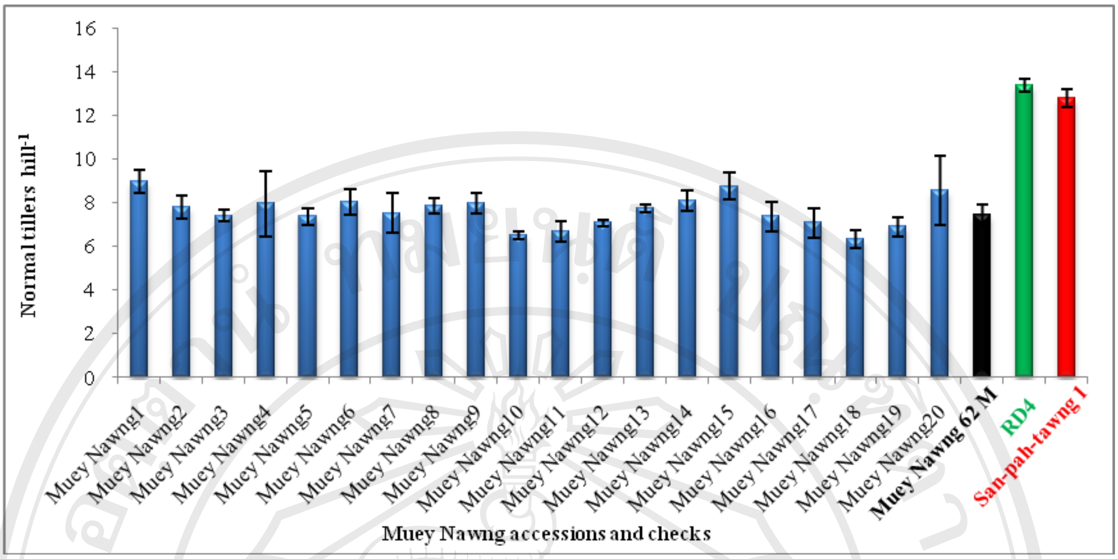

Figure 3.3 Number of normal tillers in 20 Muey Nawng accessions and three check varieties (Muey Nawng 62 M, RD4 (resistant) and San-pah-tawng 1 (susceptible) at maturity in farmer's field at Mae Moot village. Error bars represent ± SE (n=4).

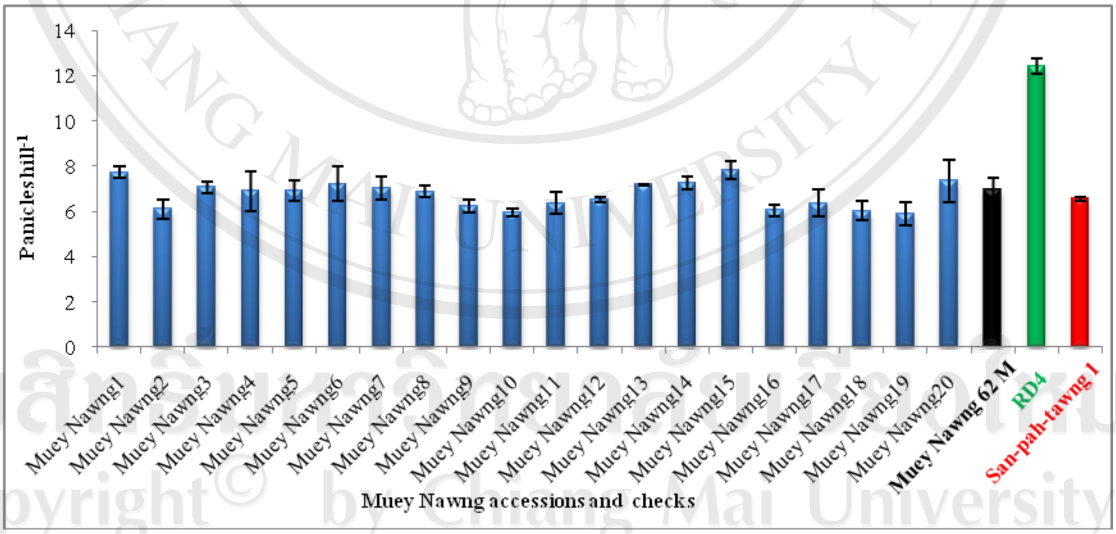

Figure 3.4 Number of panicles of 20 Muey Nawng accessions and three check varieties (Muey Nawng 62 M, RD4 (resistant) and San-pah-tawng 1 (susceptible)) at maturity in farmer's field at Mae Moot village. Error bars represent ± SE (n=4).

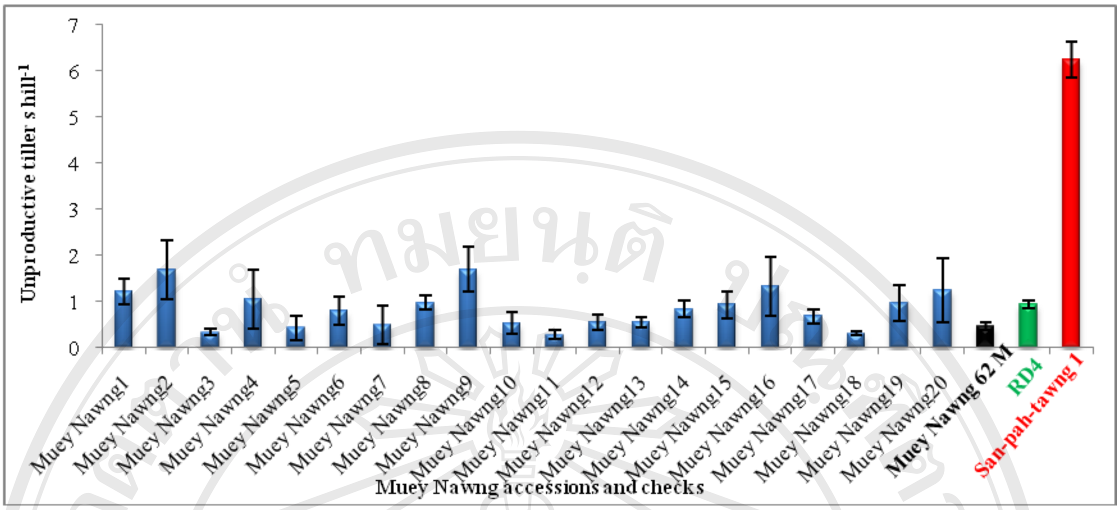

Figure 3.5 Number of unproductive tillers in 20 Muey Nawng accessions and three check varieties (Muey Nawng 62 M, RD4 (resistant) and San-pah-tawng 1 (susceptible)) at maturity in farmer's field at Mae Moot village. Error bars represent ± SE (n=4).

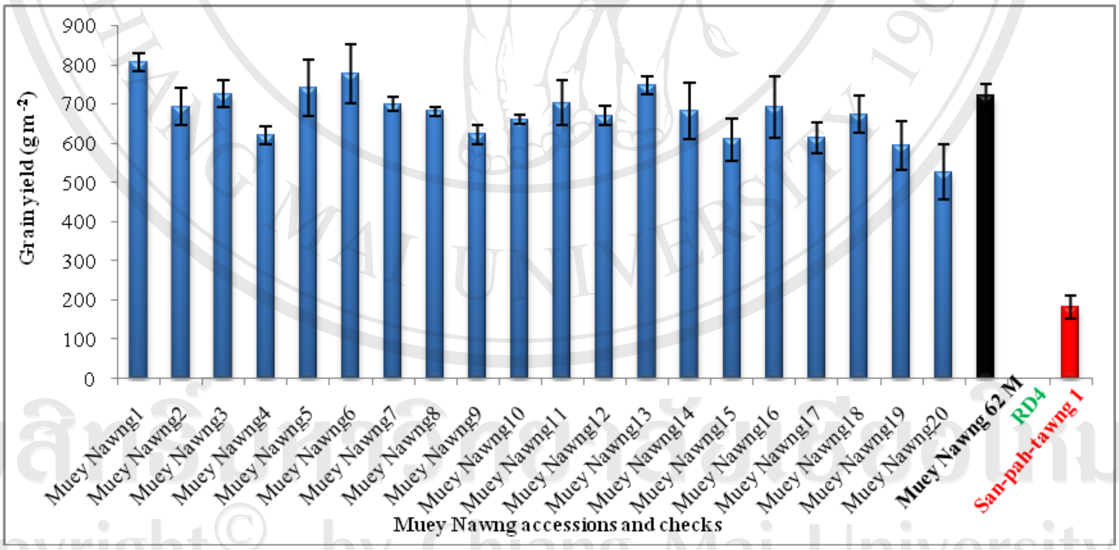

Figure 3.6 Grain yield (at 14% grain moisture content) of 20 Muey Nawng accessions and three check varieties (Muey Nawng 62 M, RD4 (resistant) and San-pah-tawng 1 (susceptible)) at maturity in farmer's field at Mae Moot village. Error bars represent ± SE (n=4). *No data for grain yield of RD4 due to bird damage.

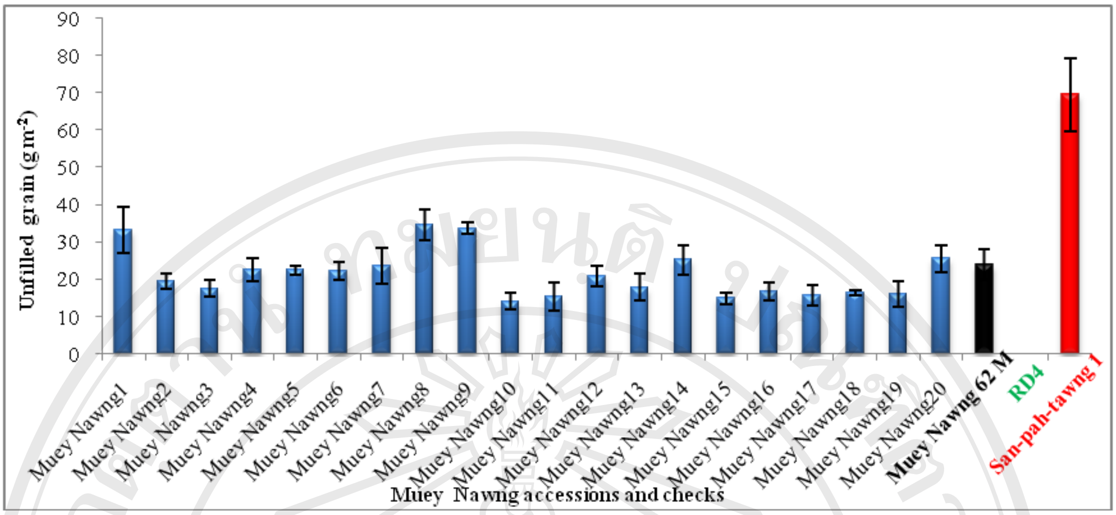

Figure 3.7 Unfilled grain of 20 Muey Nawng accessions and three check varieties (Muey Nawng 62 M, RD4 (resistant) and San-pah-tawng 1 (susceptible)) at maturity in farmer's field at Mae Moot village. Error bars represent ± SE (n=4). *Unfilled grain was not determined in RD4 because of damage by bird.

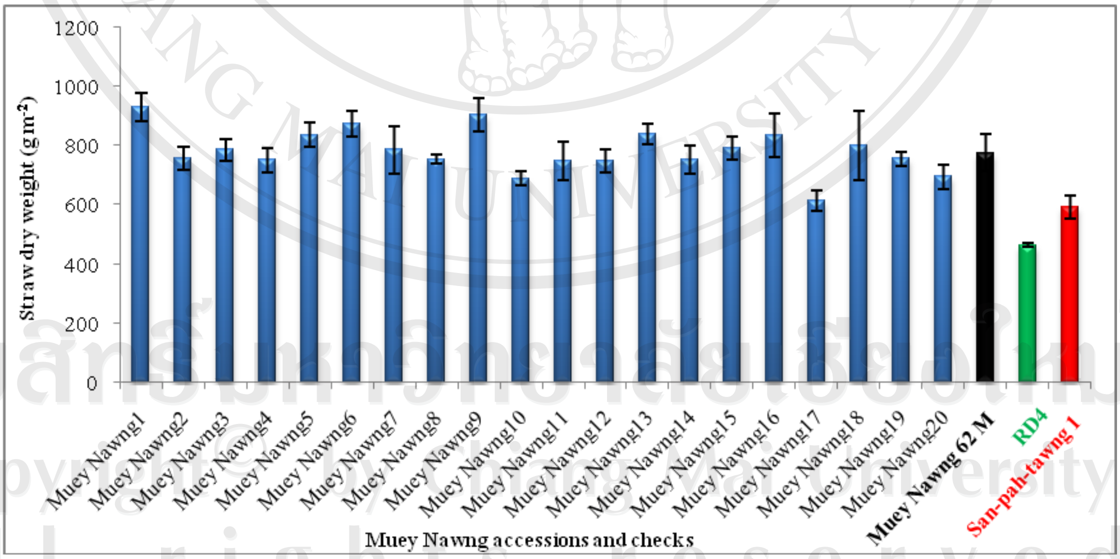

Figure 3.8 The straw dry weight of 20 Muey Nawng accessions and three check varieties (Muey Nawng 62 M, RD4 (resistant) and San-pah-tawng 1 (susceptible)) at maturity in farmer's field at Mae Moot village. Error bars represent ± SE (n=4)

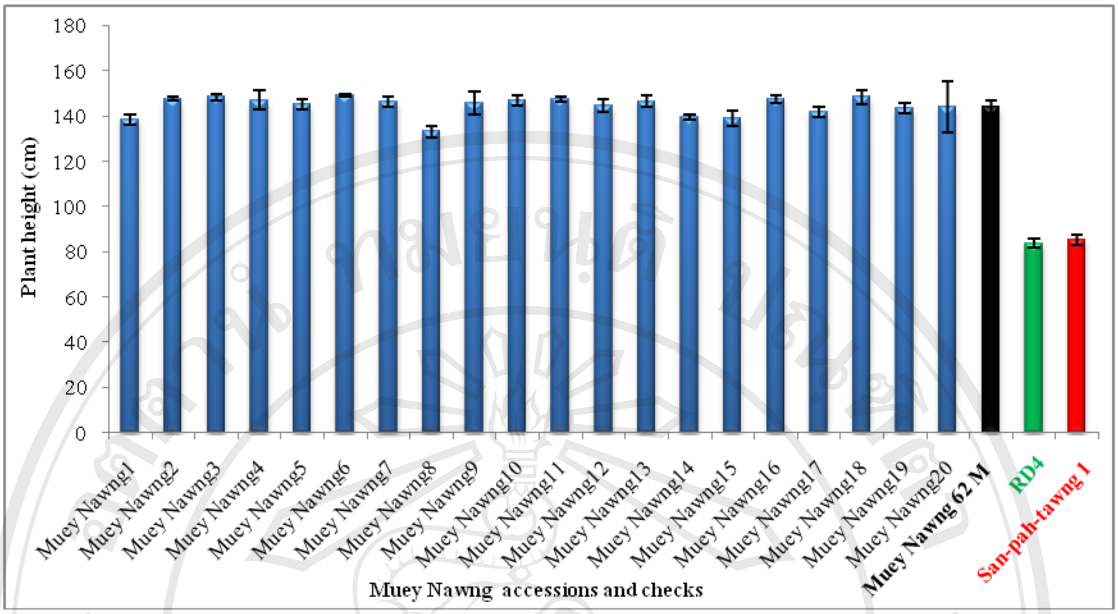

Figure 3.9 Plant height (cm) of 20 Muey Nawng accessions and three check varieties (Muey Nawng 62 M, RD4 (resistant) and San-pah-tawng 1 (susceptible)) at maturity in farmer's field at Mae Moot village. Error bars represent ± SE (n=4).

3.3.3 Comparing accessions of Muey Nawng with different gall midge resistance and improved rice varieties in environments with different gall midge damage

At vegetative stage

The normal tillers of five Muey Nawng accessions and three check varieties were not significantly different at 60 and 80 days after transplanting in Mae Moot village (MM, gall midge presence). But at Chiang Mai University (CMU, gall midge absence), there were some differences between the Muey Nawng accessions in the number of their normal tillers at both 60 and 80 days from transplanting, which were significantly fewer than in KDML105 and RD6. At 60 days, while most of 5 Muey Nawng accessions were similarly the normal tillers hill^{-1} with Muey Nawng 62 M, except, MN20 had slightly fewer tillers hill^{-1} than in MN1. At 80 days after transplanting, the 5 Muey Nawng accessions and Muey Nawng 62M had about the same number of tillers, while KDML105 and RD6 had more tillers (Table 3.6).

The rice plants of all varieties were free of gall midge infestation at Chiang Mai University. At 60 and 80 days after transplanting, Muey Nawang accessions showed significant variation in the percentage of gall midge infestation at Mae Moot village. Those susceptible accessions as well as the susceptible checks were found to have percentage infestation at 60 days that ranged from 15% in MN9 and KDML105, to 18% in MN8 and 29% in RD6; and increased to 41% in MN 8, 31% in MN9, and more than 40% in RD6 and KDML105 (Table 3.7). No gall midge infestation was found in MN1, MN6 and Muey Nawng 62 M at both 60 and 80 days, with less than 1% infestation in MN20

At Maturity stage

The normal tillers hill^{-1} of five Muey Nawng accessions and three check varieties was significantly different at the both locations (Table 3.8). At Chiang Mai University (gall midge absent), the number of normal tillers were about the same in the five accessions of Muey Nawng and Muey Nawng 62 M: 7.5±0.3 tillers hill^{-1}, with more tillers in KDML105 (10 tillers hill^{-1}) and RD6 with 9 tillers hill^{-1}. At Mae Moot village (gall midge present), there were significant difference among the Muey Nawng accesses ions in the number of their normal tillers hill^{-1}. The highest number of tillers was 15.5 tillers hill^{-1} in MN8, followed by MN9, whereas MN1, MN6, MN20 and Muey Nawng 62 M were in the same range at 10.2±0.7 tillers hill^{-1}. The highest numbers of tillers were in the susceptible checks: 19 tillers hill^{-1} in RD6 and 16 tillers hill^{-1} in KDML105.

At Chiang Mai University (gall midge absent), almost all of the tillers developed into productive panicles. In the presence of gall midge at Mae Moot the proportion of tillers that developed into panicles differed significantly among the genotypes. Those that had 90% or more of their tillers developed into panicles were MN1, MN6, MN20, and the gall midge resistant check Muey Nawng 62 M. The gall midge susceptible check RD6 had only 60% of its tillers becoming productive panicles and KDML105 75%. These were comparable to MN8 and MN9 with only 70% of their tillers becoming productive tillers. Thus, MN1, MN6, MN20, and the gall midge resistant check Muey Nawng 62 M had fewer than 1 unproductive tiller hill^{-1}, where as MN8 and MN9 had 4-5 unproductive tillers hill^{-1}, which was about the same as KDML105. Gall midge susceptible check RD6 had the highest number of unproductive tillers, at 7 unproductive tillers hill^{-1}.

Grain yield of the five Muey Nawng accessions and three check varieties was significantly different at both locations (Table 3.9). Where gall midge was absent at Chiang Mai University, the grain yield of some Muey Nawng accessions were mostly similar to the standard Muey Nawng 62 M and also KDML105, averaging 559±15 g m^{-2}. Exception was MN20 which had significantly lower yield, by 10%. At the gall midge absent site at CMU, RD6 out yielded all other varieties with a grain yield of 649 g m^{-2}. However, at the gall midge infested site at Mae Moot, gall midge susceptible RD6 yielded only 71% of that the gall midge free site, and KDML105 only 84%. There was also significant variation in grain yield of Muey Nawng accessions at gall midge infested Mae Moot. MN8 and MN8 had similar grain yield as gall midge susceptible RD6 and KDML105, averaging 498±31 g m^{-2}. The highest grain yield observed at Mae Moot was from MN6 with 706 g m^{-2}, followed by MN1, MN20 and gall midge resistant check Muey Nawng 62 M, with an average of 635±31 g m^{-2}. The unfilled grain of 5 Muey Nawng accessions and 3 check varieties was not significantly different at Chiang Mai University (gall midge absence) but it was significantly different at Mae Moot village (gall midge presence) (table 3.9). At Mae Moot village (gall midge presence), the unfilled grain was the highest in RD6, KDML105, MN8 and 9. While MN1, 8, 20 and KDML105 had the similar unfilled grain, at lower level. In addition, the weight of unfilled grain was not different between MN1, MN6 and Muey Nawng 62 M.

Table 3.6 Number of normal tillers in five Muey Nawng accessions with different gall midge resistance and three check varieties (Muey Nawng 62 M (resistant), KDML105 and RD6 (susceptible)) at 60 and 80 days after transplanting at Multiple Cropping Center, Chiang Mai University (CMU, gall midge absent) and Mae Moot village (MM, increased gall midge infestation with artificial lighting).

Variety	**60 days after transplanting**		**80 days after transplanting**	
	CMU	**MM**	**CMU**	**MM**
	Productive tillers hill^{-1}			
Muey Nawng accessions				
MN1	8.7 B	9.8	7.4 CD	9.3
MN6	8.5 BC	11.2	7.6 BC	9.6
MN8	8.2 BC	11.3	7.1 CD	9.2
MN9	8.4 BC	10.0	7.3 CD	8.9
MN20	7.9 C	11.3	7.0 CD	8.7
Check varieties				
Muey Nawng 62 M	8.2 BC	10.8	6.8 D	8.9
KDML105	10.3 A	11.1	9.3 A	8.1
RD6	10.2 A	11.1	8.2 B	8.9
F-test	*	NS	*	NS

*=significant at P<0.05. NS=not significant at P<0.05. Difference between varieties in the same column is indicated by different uppercase letters.

Table 3.7 Gall midge damage (%) in five Muey Nawng accessions with different gall midge resistance and three check varieties (Muey Nawng 62 M (resistant), KDML105 and RD6 (susceptible)) at 60 and 80 days after transplanting at Multiple Cropping Center, Chiang Mai University (CMU, gall midge absent) and Mae Moot village (MM, increased gall midge infestation with artificial lighting).

Variety	60 days after transplanting		80 days after transplanting	
	CMU	MM	CMU	MM
		(%)		
Muey Nawng accession				
MN1	0	0 C	0	0 B
MN6	0	0 C	0	0 B
MN8	0	18.4 AB	0	40.9 A
MN9	0	15.3 B	0	30.7 A
MN20	0	0.8 C	0	0.2 B
Check variety				
Muey Nawng 62 M	0	0 C	0	0 B
KDML 105	0	15.4 B	0	43.2 A
RD6	0	28.5 A	0	45.5 A
F-test		*		*

*=significant at $P<0.05$. Difference between varieties in the same column is indicated by different uppercase letters.

Table 3.8 Number of normal tillers, panicles and unproductive tillers in five Muey Nawng accessions with different gall midge resistance and three check varieties (Muey Nawng 62 M (resistant), KDML105 and RD6 (susceptible)) at maturity stage at Multiple Cropping Center, Chiang Mai University (CMU, gall midge absent) and Mae Moot village (MM, increased gall midge infestation with artificial lighting).

Variety	**Normal tillers hill^{-1}**		**Panicles hill^{-1}**		**Unproductive tillers hill^{-1}**	
	CMU	**MM**	**CMU**	**MM**	**CMU**	**MM**
Muey Nawng accession						
MN1	8.1 C	10.2 C	7.2 C	9.8 CD	0.9	0.3 D
MN6	7.6 CD	10.1 C	7.1 CD	9.9 CD	0.5	0.7 D
MN8	7.4 D	15.5 AB	6.7 CD	10.5 BC	0.7	4.9 AB
MN9	7.3 D	13.0 BC	6.6 D	9.3 CD	0.7	3.7 BC
MN20	7.5 CD	11.2 C	7.0 CD	10.3 BCD	0.6	0.9 CD
Check variety						
Muey Nawng 62 M	7.1 D	9.4 C	6.7 CD	8.8 D	0.4	0.6 D
KDML105	10.1 A	16.4 AB	9.4 A	12.3 A	0.7	4.1 B
RD6	8.9 B	18.9 A	8.6 B	11.5 AB	0.2	7.4 A
F-test	*	*	*	*	NS	*

*=significant at $P<0.05$. NS=not significant at $P<0.05$. Difference between varieties in the same column is indicated by different uppercase letters.

Table3.9 Grain yield and unfilled grain in five Muey Nawng accessions with different gall midge resistance and three check varieties (Muey Nawng 62 M (resistant) KDML105 and RD6 (susceptible)) at Multiple Cropping Center, Chiang Mai University (CMU, gall midge absent) and Mae Moot village (MM, increased gall midge infestation with artificial lighting).

Variety	Grain yield (g m^{-2})		Unfilled grain (g m^{-2})	
	CMU	**MM**	**CMU**	**MM**
Muey Nawng accession				
MN1	584.6 B	665.9 AB	40.1	30.2 BCD
MN6	553.5 BC	705.7 A	41.8	20.5 CD
MN8	545.7 C	521.2 C	37.5	34.1 ABC
MN9	553.1 BC	525.3 C	37.7	45.8 A
MN20	489.0 D	606.9 B	33.4	30.9 BCD
Check variety				
Muey Nawng 62 M	546.9 BC	633.4 AB	33.7	18.9 D
KDML 105	569.0 BC	480.3 C	26.0	39.1 AB
RD6	649.1 A	463.4 C	25.9	46.2 A
F-test	*	*	NS	*

*=significant at P<0.05. NS=not significant at P<0.05. Difference between varieties in the same column is indicated by different uppercase letters.

3.4 Discussion

Responses to gall midge were consistently different among rice varieties. The resistant varieties of Muey Nawng and Phrae 1 had lower infestation by gall midge at 60, 80 days after transplanting and heading stage than RD6 and Nahng Gao in Experiment 3.2.1. These confirmed earlier results (see in Chapter 2). Muey Nawng had the highest straw dry weight which is consistent with its belonging to the tall, traditional plant type. The grain yield of Muey Nawng was also higher than other varieties in this site with gall midge problem. In contrast, the general of susceptible rice varieties to the gall midge infestation were found in tillering stage have the initiation of the onion leaf (biotype of gall midge in Thai) or silver shoot and high number of tillers and stunting rice. At the flowering stage gall midge cannot infest rice panicle but it continued to develop silver shoots in new, non-productive tillers and produce more adults (Tayathum *et al*., 1995). Kumar *et al*. (2008) reported that the higher levels gall midge infestation led to significant yield loss and an increase of 5% in silver shoots was found to cause significant loss in rice in Coastal Karnataka, India. This study also found that the high percentage of gall midge infestation varieties had the lowest the grain yield and highest the number of unproductive tillers hill^{-1}and unfilled grain. However, the plant height of RD6 was 146 cm, slightly shorter than its standard height of 150 cm (Rice Department, 2009). It is not clear if this was the effect of this particular location or an effect of the gall midge.

It is well known that local rice varieties are generally diverse genetically among and within accessions kept by farmers. The variation in gall midge infestation of 20 Muey Nawng accessions, from no infestation to high percentage of gall midge infestation in the same order of susceptible check San-pah-tawng 1, confirmed genetic diversity in a local rice variety, in an agronomically important trait. Moreover, the differentiation of 20 Muey Nawng accessions was also found in the number of normal tillers hill^{-1}, unproductive tillers hill^{-1}, plant height, grain yield, unfilled grain and straw dry weight. These results were confirmed an earlier finding in seven Muey Nawng accessions at five locations, in Northern Thailand (Supamongkol, 2006). Other studies have reported variation within local rice varieties in other useful traits. Pintasen *et al*. (2007) reported up to three fold variation in grain Fe in farmer's seeds of local up land rice varieties from Huai Tee Cha village in Northern Thailand. Phattarakul (2008) showed that the variation tolerance to aluminum toxicity and soil acidity within accessions upland rice varieties and between the accessions that were reflected in yield differences in acidic soil in Huai Tee Cha in Mae Hong Son Province in northern Thailand.

The responses of resistance reaction to gall midge in rice varieties are different among rice varieties. The non-preference type is identified in rice varieties that are free of gall midge infestation. Likewise the no infestation by India gall midge in the varieties Usha, Samaridhi and Bd 6-1 were identified the gall midge resistant gene *Gm1* Chaudhary *et al*., (1986). The resistance to gall midge at Mae Moot in Muey Nawng accessions (MN3, MN5, MN6 and MN18) and Muey Nawng 62 M and susceptibility in other accession in the same level as susceptible checks will need to be further investigated. There is a possibility that some of the Muey Nawng accessions may actually be susceptible or that the gall midge responses of the accession may vary with different gall midge populations. Indeed, Supamongkol (2006) found variation in gall midge response among accessions of Muey Nawng in their response to gall midge in different locations. However, the infestation by rice gall midge can lead to the production of more new tillers in susceptible varieties to replace the tillers that were damaged and become silver shoots in the vegetative stage (Inthavong, 1999). Similarly, the response of susceptible of KDML105, RD6, MN8 and MN9 was same number of normal tillers at vegetative stage and number of normal tillers and panicles at maturity with as resistant of MN1, MN6, MN20 and Muey Nawng 62 M at highly gall midge infestation (Experiment 3.2.3). This result confirm in the absence of gall midge, the susceptible varieties had produced more or same the productive tillers, normal tillers, panicles and grain yield with as resistant varieties. This agree with Nacro *et al*. (1996) suggested that infestation by rice gall midge on rice plant resulted in the compensatory production at tillers which developed in response to gall midge infestation but the compensation was not sufficient to make up for the loss of yield due to the damage tillers.

In conclusion, the local variety Muey Nawng has again been shown to be resistant to gall midge, confirming the results in Chapter 2. It showed no or little infestation by rice gall midge, and had the highest grain yield, straw dry weight, the lowest in unproductive tillers and unfilled grain. However, the 20 Muey Nawng accessions collected from different farmers in three provinces were different in their reaction to gall midge in farmer's field condition. The percentage of gall midge infestation was varied form no infestation to high percentage in the same range as susceptible checks. This variation in gall midge responses was found in number of normal tillers, panicles, unproductive tillers, grain yield and unfilled grain. It remains to be further investigated how reaction of 20 Muey Nawng accessions infest by different biotypes of gall midge in different provinces in Thailand. These are explored in Chapter 4.