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Agronomic Performance of Four CIMMYT Wheat Genotypes in the Tropical Environment of Semarang Regency in Central Java, Indonesia

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Abstract. Several wheat genotypes collected by the International Maize and Wheat Improvement Center (CIMMYT) in Mexico can be introduced in the tropical regions of Indonesia to support national wheat production. Currently, four genotypes originating worldwide are available for introduction: CWI 10553, CWI 17903, CWI 89948, and CWI 8124. This research aims to identify the performance and yield of these genotypes grownin a controlled environment. Wheat seeds were cultured in MS medium then transplanted into a pot filled with mixture of soil and compost. Pot cultivation was carried out at a latitude of 800 m asl. Fertilizer was applied four times: 1) 2 g of guano during transplanting; 2) 2 g of guano + 1 g of urea + 1 g of ZA + 2 g of P_2O_5 + 1 g of KCl three weeks after transplanting, 3) 2 g of guano 6 weeks after planting, and 4) 1 g of urea + 1 g of ZA + 2 g of P_2O_5 + 1 g of KCl during grain filling. By the end of the growing season, 10 plants of CWI 10553, 2 plants of CWI 17903, 4 plants of CWI 89948, and 10 plants of CWI 8124 survived until grain production. CWI 8124 seemed to adapt well as indicated by its relatively high number of tillers, number of seeds per spike, and grain weight per plant. CWI 89948 was less adaptive as its height and productivity were relatively low. Generally speaking, two genotypes in the Semarang Regency of Central Java suggested for further study were CWI 8124 and CWI 10553.
Keywords: fertilizer; performance; tropics; wheat; yield

INTRODUCTION

Wheat is a widely consumed non-rice cereal food crop in Indonesia thus vital to support national food security. Wheat has the potential to be produced in large scale in the tropical environment of Indonesia. For this purpose, wheat gene pool is an important factor to consider so that suitable genotypes can be selected and improved for specific tropical locations like Indonesia (Casagrande et al., 2022; Fadli et al., 2022; Fari et al., 2020; Nuraeni et al., 2021; Putri et al., 2020). Several wheat genotype collections in the *International Maize and Wheat Improvement Center* (CIMMYT) in Mexico can be introduced into Indonesia farmlands, but they may perform differently thus give different yields. Four wheat genotypes obtained from CIMMYT were available to be agronomically evaluated: CWI 10553, CWI 17903, CWI 89948, and CWI 8124. They are originally from different regions worldwide. CWI 10553 (Sonop, *pedigree* = Kleintrou/Pelgrim) and CWI 8124 (Pioneer, *pedigree* = Riga/Preston) are respectively from South Africa and Mozambique. Both genotypes are improved cultivars resulting from breeding. Sonop wheat is the first spring bread wheat cultivated in its region and was produced by the Elsenburg College of Agriculture (Nhemachena & Kirsten, 2017). Sonop wheat is highly resistant to loose smut disease caused by the fungus *Ustilago tritici* (Thambugala et al., 2020). Meanwhile, information and research results on Pioneer is not available.

CWI 17903 (T.SPELTA PI348489) is originally from Spain and one of the local landrace varieties. This spelta wheat (*Triticum aestivum* L. ssp. *spelta* Thell., 2n = 6× = 42, A^uA^uBBDD) is an ancient wheat type that resulted from the natural crossing of emmer type (*T. turgidum* spp. *dicoccum* Schrank em. Thell.) and *Aegilops tauschii* ssp. *strangulata* Coss. (Huertas-García, Guzmán, et al., 2023). Spelta wheat contains distinct nutritional quality compared to common wheat (Huertas-García, Tabbita, et al., 2023). It is vulnerable to powdery mildew, brown rust disease, as well as water lodging. Its harvest index is similar to emmer's but lower than bread wheat's in general (Konvalina et al., 2010). CWI 89948 (Kavkaz Yarovoi,pedigree = Lutescens 314 H 147/Bezostaya 1) originally comes from Russia. It is a breeding line, yet information and research on this

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accession is not available.

These four genotypes have never been introduced in Indonesia in which the tropical environment is distinct compared to their original growing conditions. Therefore, whether theywill survive and produce yields when grown in Indonesia is unknown. The aim of this research is to identify the performance and yield of four CIMMYT wheat genotypes in a controlled environment.

METHODS

This research was performed in The Laboratory of Tissue Culture and in a UV-plastic greenhouse of the Faculty of Agriculture and Business of Satya Wacana Christian University in Central Java (800 m asl). The research was conducted from July to November 2023. Wheat seeds were provided by CIMMYT in Mexico. Seeds of each genotype were initially cultured in MS medium in The Laboratory of Tissue Culture. This method was chosen to anticipate seed germination failure if they were directed sown in the soil as the numbers of available seeds were limited. There were 25 seeds of CWI 10553, 12 seeds of CWI 17903, 25 seeds of CWI 89948, and 25 seeds of CWI 8124 grown using MS culture method. Nonetheless, not every seed could germinate into plantlets and not every plantlet survived the post-culture acclimatization stage. We transplanted only the green, healthy, and upright wheat seedlings into soil and compost mix medium in black polybags. These surviving seedlings were mostly 2-3 weeks old since the initial tissue culture. Each polybag was used to grow one seedling, they then were arranged in a UV-plastic greenhouse.

All seedlings received equal agronomic treatments including fertilization, water, and pest control. Seedlings were watered each day until the soil was relatively wet. Once in a while, the water was mixed with commercial biofertilizers available in the market. There were four fertilization frequency: 1) 2 g of guano on the transplanting day; 2) 2 g of guano + 1 g of urea + 1 g of ZA + 2 g of P_2O_5 + 1 g of KCl on the 3rd week post transplanting; 3) 2 g of guano on the 6th week post transplanting; and 4) 1 g of urea + 1 g of ZA + 2 g of P_2O_5 + 1 g of KCl during grain filling stage. Since not each seedling survived until the generative stage, we chose to collect data only from wheat plants passing through the generative stage and producing wheat grains. In the end of the research, we used data from 10 plants of CWI 10553, 2 plants of CWI 17903, 4 plants of CWI 89948, and 10 plants of CWI 8124 to assess the performance and yieldof each genotype.

The wheat plants were harvested when they showed physiological maturity as indicated by golden or yellowish habitus and hard kernels. On harvest day, we measured the height of each plant and the length of each spike. We counted the number of tillers and productive tillers as well as the number of grains per spike. After air-drying the grains for 2-3 days, we then weighed the individual grains, the total grains of each spike, and the total grains of each plant. Since the total grain numbers of each genotype harvested at the end of the growing season were not adequate, we could only weigh the individual grain weight instead of the weight of 1000 seeds.

RESULTS AND DISCUSSION

In general, the four tested wheat genotypes showed similar morphological appearance (**Figure 1**). All genotypes are erect type with slightly different habitus color. CWI 17903 turned color into golden white by the end of the generative phase, while the other three genotypes changed into brown.

The experimented four genotypes showed varied agronomic characteristics as indicated by the variation of growth and yield component (**Table 1**). CWI 10553 underwent a shorter life cycle (only 85 days after acclimatization) compared to the other three genotypes (101-120 days post acclimatization). This was likely due to its relatively low adaptability in tropical areas; thus, the plants shortened their life cycle.

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CWI 10553 | CWI 17903 | CWI 89948 | CWI 8124

Figure 1. Morphological appearance of the four genotypes in the end of experiment

As can be seen in **Table 1**, CWI 17903 plants possessed a relatively tall habitus (48.80 cm),while CWI 89948 plants were relatively shorter (35.39 cm). The height of all experimented genotypes was evidently lower than that of worldwide wheat varieties and of all genotypes ever grown in Indonesia. In comparison, the average height of worldwide wheat plants is 82 cm in Europe and 88 cm in Asia (Tadesse et al., 2010). The average height of other genotypes tested in Indonesia at similar elevations or temperature ranges (1.100 m asl, 20-22°C) ranged from 60-85 cm (Altuhaish et al., 2014; Syahruddin et al., 2019).

Table 1. Agronomical characteristics of four genotypes provided by CIMMYT when grown in research location. Data are presented as means and standard of deviation

Parameters	**CWI 10553 (n=10)**	**CWI 17903 (n=2)**	**CWI 89948 (n=4)**	**CWI 8124 (n=10)**
Harvest age (days after acclimatization)	85	120	115	101
Plant height (cm)	43.99 ± 10.53	48.80 ± 10.48	35.39 ± 13.22	40.18 ± 10.26
Number of tillers	3.60 ± 1.51	3.00 ± 1.41	2.25 ± 0.96	7.20 ± 0.92
Number of productive tillers	2.90 ± 0.57	3.00 ± 1.41	1.75 ± 0.96	6.40 ± 0.70
Spike length (cm)	5.78 ± 3.72	7.67 ± 1.69	8.26 ± 3.42	5.85 ± 0.88
Number of grains per spike	17.75 ± 13.12	7.50 ± 6.47	8.29 ± 3.15	20.80 ± 13.59
Number of grains per spike : spike length	3.00 ± 0.81	1.01 ± 0.87	1.10 ± 0.46	2.98 ± 1.44
Grain weight per spike (g)	0.38 ± 0.32	0.18 ± 0.18	0.13 ± 0.09	0.45 ± 0.30
Individual grain weight (g)	0.02 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.02 ± 0.01
Grain weight per plant (g)	1.51 ± 0.43	0.53 ± 0.37	0.22 ± 0.12	2.26 ± 0.45

The height of these four genotypes were still lower than that of the wheat plants tested at lower altitude in Indonesia (<400 m asl, 26-32°C) which could stand up to 62 cm (Nur et al., 2014; Rachmadhani et al., 2017). These four genotypes were only slightly taller than those experimented by Altuhaish etal. (2014) at 176 m asl (around 29°C) whose habitus could only grow up to 35-36 cm. Wheat growing in warmer environment are usually shorter (Syahruddin et al., 2019). This research has shown that the landrace spelta wheat

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"CWI 17903" has the capability to survive the warm tropical climate of Indonesia despite it is originally from the Mediterranean Spain. Meanwhile, the originally subtropical Russian wheat "CWI 89948" is less adaptive to the higher temperature of Indonesia.

Height variation amongst plants of the same genotype was relatively large (± 20-30% of the average plant height) and this variation was found in all genotypes. This wide variation might indicate the distinct adaptability of every plant having similar genetic characteristics: some might grow taller (maximum height) while others might grow shorter (minimum height). The largest variation was found in CWI 10553 (**Figure 3**). This genotype, which is originally from subtropical South Africa, has resulted in wheat plants having the tallest habitus (> 70 cm) as well as the shortest one (< 30 cm).

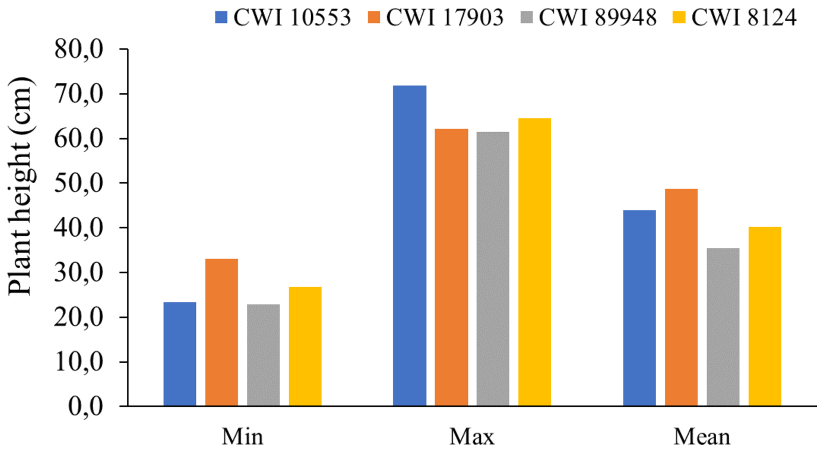

Figure 3. The minimum, maximum, and mean of plant height of four wheat genotypes from CIMMYT

In dry regions, plant height is known to be positively correlated with wheat yield. Nonetheless, excessively tall plants might not always provide agronomical benefits, especially during the rainy season, as they will trigger waterlog in soil and disease incidence (Tadesse et al., 2010). In an irrigated farming system, shorter cultivars would be more beneficial as they prevent waterlogging. Meanwhile, taller cultivars are more suitable to be grown in dry area such as the wheat belt of Australia (Hyles et al., 2020).

Early maturity occurred in CWI 10553 plants (85 days post acclimatization), while later harvest day was found in CWI 17903 plants (120 days) and CWI 89948 plants (115 days). Harvest age is one prominent characteristic to be sought to create productive tropical wheat cultivars. This parameter is influential in determining the duration of wheat grain filling (Syahruddin et al., 2019). The longer harvest age will provide wheat plants with more accumulated photosynthate in the spikelet, thus increasing grain weight. Compared to other genotypes grown in similar elevations, the harvest age of CWI 10553 plants was slightly shorter and resembled the growth of wheat plants grown in tropical low-altitude and warmer areas. In the low-altitude regions of Lombok of Indonesia in which the temperature reached 30°C during certain periods, the harvest age of several wheat cultivars ranged between 76 to 102 days. In the high-altitude sites where the temperature decreased, the harvest age of the same genotypes became longer ranging from 94 to 120 days (Zubaidi et al., 2018). Shorter harvest age was also found in 18 wheat genotypes tested in the lowland of Mojokerto (64 m asl) in which grain maturity took place at the age of 73 to 96 days (Rachmadhani et al., 2017). The harvest age of CWI 10553 was distinctly shorter than that of 62 wheat genotypes/accessions experimented by Syahruddin et al. (2019)

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under high temperature regime and severe drought. In such condition, the harvest age occurred at the age of 104-132 days.

All genotypes in this research seemed to have varied ability of producing tillers. CWI 8124 produced a relatively higher number of tillers and productive tillers compared to other three genotypes. The average number of tillers and productive tillers of this genotype were respectively 7.2 and 6.4 per plant. These were 2-3 times higher than those of the other three genotypes. The lowest tiller production was found in CWI 89948 (on average 2.25 tillers and 1.75 productive tillers per plant).

The number of tillers produced by several wheat genotypes grown and tested in Indonesia varied depending on the genetic characteristics and the environment. Tiller production of CWI 8124 was relatively higher than the tillers produced by all ever experimented wheat cultivars. Under adequate water supply (81-100% of field capacity), fifteen mutant genotypes tested by Farid et al. (2020) could only produce 1-5 tillers per plant. In low-altitude regions (176 m asl), eighteen wheat genotypes experimented by Altuhaish et al. (2014) could only produce 3-4 tillers per plant. Several mutant wheats grown by Nur et al. (2014) produced 2 productive tillers at lower elevation (< 400 m asl) and 4-5 tillers at higher altitude (> 1000 m asl). Tiller production of CWI 8124 was only surpassed by the wheat plants grown by Altuhaish et al. (2014) at high altitude (1100 m asl). Under the relatively lower temperature of this region, wheat plants could produce 9-17 tillers.

Reduction of tiller production is common in wheat plants when cultivated in warmer environment (Altuhaish et al., 2014). This indicates the vulnerability of tiller growth and development toward higher temperature. CWI 8124 originally comes from the tropical Mozambique thus the plants were not severely affected by the tropical environment of Indonesia. However, different phenomenon occurred in the other three genotypes as they wereless adaptive to the warmer condition of the tropics. The number of wheat tillers is an instrumental factor to include when selecting appropriate genotypes for optimum production, yet it shouldn't be the only yield component to be considered. This is mainly due to the fact that higher number of tillers is not necessarily correlated with higher grain yield especially when additional tillers are not fertile (Hyles et al., 2020).

The average spike length, number of grains per spike, and grain weight per spike varied among genotypes. CWI 17903 and CWI 89948 plants produced relatively longer spikes (7-8 cm), while CWI 10553 and CWI 8124 had relatively shorter spikes (5-6 cm). Vice versa, genotypes having shorter spikes apparently produced more grains (17-21 grains per spike) while plants having longer spikes produced only 7-8 grains per spike. The length of spikes produced by genotypes experimented in this research was relatively similar to other wheat plants ever tested in Indonesia. Nonetheless, they produced fewer grains in each spike. For comparison, the length of wheat spikes grown by Altuhaish et al. (2014) ranged between 7.95-12.78 cm, and the number of seed production ranged from 36.80-53.90 grains per spike. The length of spike in wheat plants cultivated by Rachmadhani et al. (2017) were around 7.55 to 9.82 cm, and the number of grains produced in each spike ranged from 28.17 to 44.33 seeds. Other wheat genotypes grown by Nasution et al. (2019) produced spikes having length of 5.41to 9.34 cm and yielded around 10 to 20 grains in each spike.

This result indicates that longer spikes will not guarantee that wheat plants will produce more grains. This is supported by the ratio between the number of grains per spike to the lengthof the spike. In this case, CWI 10553 and CWI 8124 could produce 2.9-3 grains per 1 cm of spike while the other two genotypes could only produce one grain. This simply means the relation between spike length and the increment of grain production in each spike strongly depends on wheat genetic characteristics. This pattern is

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different compared to the research result of Nur et al. (2014). The spike length of several wheat genotypes experimented in low-altitude sites ranged from 5.1-7.1 cm in which around 18-32 grains could be produced in each spike. The spike becomes longer up to 8.4-10.7 cm when they grow in high-altitude lands (1000 m asl). As the spikes become longer, the grain production increases up to 34-40 seeds per spike.The declining number of grains produced by the four CIMMYT genotypes tested in this research was likely due to the incomplete grain filling in each spikelet. The wheat plants seemed to cope with high temperature stress by reducing grain filling.

The weight of individual seed produced by the experimented wheat genotypes was relatively similar (0.02 g) which indicates relatively similar seeds size. As grain production perspike varied among genotypes, the grain weight per spike was also different across genotypes. Genotypes having shorter spikes "CWI 10553" and "CWI 8124" produced respectively 0.38 g and 0.45 g of grains in each spike. Genotypes having longer spikes "CWI 17903" and "CWI 89948" yielded on average 0.18 g and 0.13 g of grains in each spike. They weighed more than the grain of three wheat genotypes tested by Nasution et al. (2019) which was only 0.01 g per spike.

However, they weighed less than the grains of wheat plants grown by Nur et al. (2014) at the elevation of 1000 m asl (1.3 to 17 g per spike) and by Syahruddin et al. (2019) which reached 2.18 g per spike. The size and number of seeds generally decrease when wheat plants grow under the stress of high temperature and drought. The increment of grain number produced by a wheat plant is an essential factor that determines wheat production (Zhou et al., 2021). In this research, the number of seeds produced by each spike was still lower than the prevailing research results of tropical wheats.

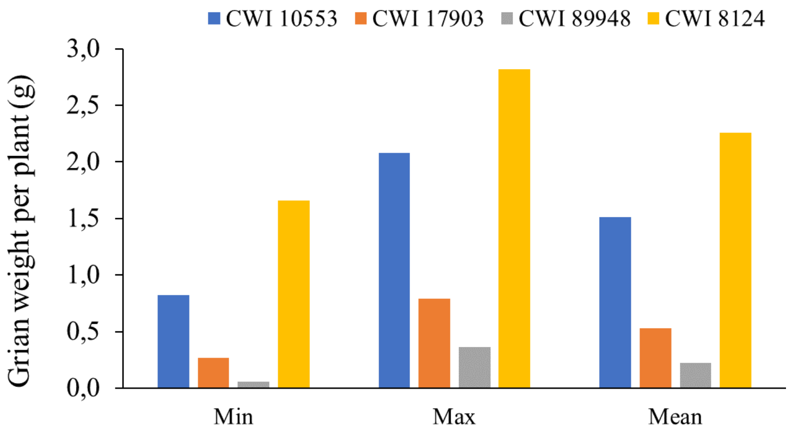

Figure 4. The minimum, maximum, and average weight of grain per plant of four CIMMYT wheat genotypes tested in the experiment

The average grain production of individual plant of CWI 8124 was the highest (2.26 g per plant). The weight ranged from 1.5 to 3 g per plant (Figure 4). This is similar to the yield of other genotypes tested in several low-altitude lands in Indonesia: 0.7-2.6 g per plant (Altuhaish et al., 2014) and 0.7-2.9 g per plant (Nur et al., 2014). The number of productive tillers and the weight of individual wheat grain seemed to play an important role in determining the total yield in each plant of each genotype. The total weight of grains of CWI 89948 was the lowest (0.22 g per plant). This is likely due to fewer productive tiller and lighter grain in each spike. Grain production of individual plant generally decreases when wheat grows in low-temperature regions as the anthesis stage is very sensitive to heat stress. Therefore, grain filling is disturbed

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(Altuhaish et al., 2014). From this result, it is obvious that CWI 8124 is relatively adaptive to the tropical environment of Indonesia as reflected by its capability of producing higher number of grains and higher grain yield per plant.

Further research can be carried out to find out the right methods to increase yields, such as defoliation to increase the effectiveness of utilizing assimilation produced from the photosynthesis process (Galushasti et al. 2024).

CONCLUSION

The limitation factor of this research is the small number of seeds for each genotype, which leads to a minimal number of observed plant individuals. Based on the result of this research, the agronomic performance and yield of four CIMMYT genotypes tested in this experiment were relatively varied when grown under a controlled environment (altitude 800 m asl). CWI 8124 genotype seemed to be more adaptive to the tropical condition as shown by its relatively higher number of tillers, higher number of grains per spike, and higher number of grains per plant. CWI 89948 genotype was relatively least adaptive as indicated by its relatively shorter habitus and inadequate grain production. Based on the results of this research, we recommend further evaluation of the agronomic performance and yield of CWI 8124 and CWI 10553 in controlled environments and open-field in other similar regions in Indonesia.

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