Research Articles

Central Mindanao University
Journal of Science

Underutilized *Senna tora* (L.) Roxb. - a highly potential multipurpose species for food, feed, medicine and climate resilience for the Philippines

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ABSTRACT

There are thousands of species in the plant kingdom but less than 200 are recognized as major crops. There is even less when it comes to food crops hence food and nutritional insecurity are major concerns in either developed or developing countries. Unfortunately, manyspecies fall under the neglected and underutilized species (NUS) category. *Senna tora* (L.) Roxb. is largely utilized in some countries especially as part of their traditional medicine but is generally known as a weed in the Philippines and henceforth technically, one of the NUS. This paper reports of findings of a series of investigations from December 2009 to November 2017 of *S. tora* in Bukidnon that documented its uses as a food, feed, and medicinal crop; *in situ* and *ex situ* ecotypic diversity in the province based on its phenotypes; and potential resilience to abiotic stresses at early vegetative stage. Use of leaves, seeds and roots as food, feed and medicine were documented in 9 of 22 barangays. Percent crude protein (PCP) of seeds and leaves ranged from 12.50% to 20.48% and 16.94-39.02%, respectively. PCP of seeds (H'=0.93) and leaves (H'=0.79 and 0.81) were highly diverse based on Standardized Shannon-Weaver Diversity Index. Plant height was estimated with moderate (H'=0.67) to high (H'=0.88 and 0.93) diversity. However, all ecotypes were non-nodulating (H'=0.00). Finally, most ecotypes were more sensitive to waterlogging than to drought for 16 days at seedling stage. Three of 10 ecotypes were sensitive only to waterlogging whereas, another three ecotypes were not sensitive to both stresses.

Keywords: underutilized species, Senna tora, multipurpose species, resilient crop, Bukidnon

INTRODUCTION

Many members of the plant kingdom are considered neglected and underutilized species (NUS). NUS are species that could be crops in one country but are considered weeds and non-valuable in another. The estimated number of plant species is around 400,000 (https://www.bgci.org/policy/1521/). Christensen and Byng (2016) reported that the accepted count is around 374,000 of which 74,273 are monocots and 210,008 are eudicots. However, the Commission on Genetic Resources for Food and Agriculture (CGRFA) reports that only less than 8000 species have records of cultivation or collected for a purpose (http://www.fao.org/nr/cgrfa/cthemes/plants/en/). The CGRFA further estimates that only 30 crops serve as primary food sources, of which only five (rice, wheat, maize or corn, millet and sorghum) provide for about 60% of food energy needs of the global population.

This is unfortunate because thousands of plant species could be beneficial to agriculture, especially to address the basic needs of food, feed, fiber, fuel and pharmaceuticals. The Philippine Statistics Authority or PSA (2017) reported that farmers, fishermen and children have the highest poverty incidence among the basic sectors in the country in 2006, 2009, 2012 and 2015 (https://psa.gov.ph/poverty-press-releases). Poverty is often coupled with food and nutritional insecurity, and is particularly ironic and sad for farmers and their children.

Senna tora (L.) Roxb. is largely regarded as a leguminous weed in the Philippines (Figure 1). It is previously known as *Cassia tora* L. with variable

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Received 7th August 2018; Accepted 13th November 2018

Figure 1. *In situ* population of *Senna tora* (L.) Roxb. in a pasture land in Kibawe, Bukidnon, Philippines

chromosome numbers: 2n=26, 28, 52, and 56; although most papers reported 2n=2x=26 (http://ccdb.tau.ac.il/Angiosperms/Leguminosae/ Senna/ Senna%20tora%20(L.)%20Roxb./). Many recent papers continue to use the name *C. tora*.

S. tora is almost ubiquitous in Bukidnon which has a variable topography and geography. Bukidnon has a total land area of 829,378 ha and is situated "between the parallels 7° 25' and 8° 38' north latitude, and the meridians 124° 03' and 125° 16' east longitude"(http://www.bukidnon.gov.ph/home/index.php/about-bukidnon/general-info/physical-feature-and-composition). Locally, *S. tora* is called "*mani-mani*" (translation: like peanut due to its leaf architecture) that is often found in pasture areas, uncultivated farmlands, and adjacent to cultivated farmlands. It has a deep tap root system and strong stem hence, is also used as a natural stake for domestic livestock (e.g. goat and cow) while grazing.

In other countries, however, it is a cultivated crop. In India, it is predominantly valued for its medicinal properties in the traditional system of Indian medicine (Pawar & D'mello, 2011). Leaves, pods, and seeds are widely used for medicinal applications (Pawar & Lalitha, 2014). The seeds are also considered alternative sources of commercial gums for their galactomannans for industrial applications (Pawar & Lalitha, 2014). Moreover, seed gums are used as thickener in foods, as well as, for non-food products such as in the manufacture of paper and textile. Hence, the viability of *S. tora* gum production in Australia was investigated (Cunningham & Walsh, 2001).

In the Philippines, *S. tora* can be considered a NUS. Hence, its local uses and phenotypic diversity in Bukidnon, crude protein concentration, and potential resilience to abiotic stresses were determined.

METHODOLOGY

Plant Materials

In situ plants of *S. tora* per municipality or city were considered "ecotypes" and were arbitrarily named after each area. These were phenotyped in three separate surveys. Seeds were collected for the *ex situ* experiments done in Central Mindanao University, Musuan, Bukidnon.

Survey

Prior informed consent per municipality and barangay was secured before the conduct of the survey, interview, and sampling. Documentation of uses of *S. tora* by the locals was done through informal interviews. On December 2009 to January 2010, in situ populations of S. tora were phenotyped in 12 municipalities of Bukidnon selected based on varying geography with emphasis on micro-climate and topography: Impasug-ong, Libona, Malitbog, Sumilao, Damulog, Kadingilan, Quezon, Cabanglasan, Lantapan, San Fernando, Kalilangan, and Pangantucan (Figure 2). Three plants either at late reproductive stage or nearing senescence were randomly selected in one barangay per municipality for sampling of mature pods (and surrounding soil). These were characterized for nine traits: plant height, number of primary branches per plant, leaf area, root nodulation, number of mature pods per plant, number of seeds per pod, weight of 100 mature seeds, percent total nitrogen (PTN) of seeds, and percent crude protein (PCP) of seeds. Seed samples were submitted for PTN analysis at the Soil and Plant Analysis Laboratory (SPAL), Department of Soil Science, College of Agriculture, Central Mindanao University (CMU) using the Kjeldahl Method. PTN value was used to estimate for percent crude protein (PCP) i.e. PCP = PTN x 6.25, where 6.25 is a default constant for estimating crude protein (FAO-UN,

Figure 2. Map of the Province of Bukidnon (http://www.bukidnon.gov.ph/home/index.php/cities-municipalities/republic-act-no-10184)

2003).

On September to October 2010, survey in the remaining eight municipalities and two cities of Bukidnon (Baungon, Manolo Fortich, Talakag, Don Carlos, Maramag, Dangcagan, Kibawe, Kitaotao, Malaybalay City, and Valencia City) was done. In this survey, two barangays were surveyed per municipality or city. Also, five randomly selected *S. tora* plants *in situ* per barangay were phenotyped for the same traits as in the first survey. However, number of mature pods per plant and seeds per pod, as well as, weight of 100 seeds were excluded since the *in situ* plants were mostly in their vegetative stages.

On December 2012 to January 2013, a validation survey was done in 13 municipalities and city of Bukidnon (Cabanglasan, Impasug-ong, Lantapan, Manolo Fortich, Talakag, Kibawe, Maramag, Quezon, San Fernando, Damulog, Pangantucan, Kadingilan, and Malaybalay City) that showed ecotypic diversity of *S. tora* plants based on the previous surveys. Five randomly selected *in situ* plants per barangay either at late vegetative stage or at early reproductive stage were characterized. Leaf samples were collected and submitted to SPAL for PTN analysis.

Potential Resilience to Abiotic Stresses

On April to November 2017, 10 ecotypes of *S. tora* that showed high (32.00-71-39.02%), intermediate (29.33-29.57%) and low (18.19-22.45%) PCP of young leaves were phenotyped for potential tolerance to 16 days of drought and waterlogging stresses at early vegetative stage. This was done at the Department of Agronomy and Plant Breeding Screenhouse, College of Agriculture, CMU following a 3x10 factorial arrangement in Randomized Complete Block Design with three replications. A replication was a recycled plastic water container with a 6.50 L capacity.

Three regimes of water stress served as the main plot factors: (i) normal (provision of ~400 ml water daily), (ii) drought (provision of ~400 ml water daily then no water for 16 days starting at 13 days after transplanting or DAT until 29 DAT), and (iii) waterlogged (provision of ~400 ml water daily then increased to ~1100 ml water daily from 13 to 29 DAT). Plants were given one week to recover from stress. Plants subjected to drought were given ~400 ml water daily for seven days, whereas, water was withheld from waterlogged plants. Data were again gathered at 36 DAT. Ten *S. tora* genotypes were the subplot factors.

Plant stress tolerance was based on the arbitrary rating scale of Jamago (2017) i.e. 1 – highly sensitive (very stunted growth and highly reduced leaf area i.e. <1/2 of plant height and leaf area of normal plants), 2 – sensitive (very stunted growth and highly reduced leaf area i.e. ~1/2 of plant height and leaf area of normal plants), 3 – moderately sensitive (stunted growth and reduced leaf area i.e. ~3/4 of plant height and leaf area of normal plants), 4 – moderately tolerant (stunted growth but normal leaf area), 5 – tolerant (normal plant height but reduced leaf area), and 6 – highly tolerant (normal plant height and leaf area).

The pot experiment was transferred outside the screenhouse for the continuance of study for recovery from stress at reproductive stage until senescence, with only rainfall as source of water. Seeds were inadequate for PTN analysis per replication hence, these were bulked per treatment instead.

Statistical Analyses

All data from the *in situ* phenotypic characterization were processed for the estimation of allelic richness using the Standardized Shannon-Weaver Diversity Index (SSWDI, H'). The scale of Jamago and Cortes (2012) was used to estimate the level of phenotypic diversity: H'=0.00 (invariant), H'=0.010-0.45 (low), H'=0.46-0.75 (moderate), H'=0.76-0.99 (high), and H'=1.00 (maximum variability). Data from the *ex situ* experiment were processed for Analysis of Variance (ANOVA) and Tukey's Test for treatment mean comparisons using the Statistical Tool for Agricultural Research (STAR) software (IRRI, 2014).

RESULTS AND DISCUSSION

Local uses of *S. tora*

In nine of 22 towns and cities of Bukidnon, *S. tora* was documented to be used as food, feed and medicine. Young leaves were used to relieve menstrual pain (Pangantucan), mixed with mungbean and canned fish (sardines) for viand (Impasug-ong), and used as ingredient for chicken stew or "*tinolang manok*" (Maramag). Extract from young leaves was an ingredient of herbal medicine to relieve muscle pain (Lantapan). Mature leaves were considered first aid treatment for wounds (Dangcagan) and for stomachache (Talakag). Leaves (young and mature) were mixed with corn bran for swine feed (Libona). Roots were roasted to make tea as cure for stomachache (Malitbog). Lastly, seeds were used to deworm both pigs and humans (Kibawe). In some supermarkets in Bukidnon, *S. tora* tea is sold as a slimming agent.

The medicinal potential of *S. tora* is affirmed by how it is utilized in other countries like India and China, and as evidenced by a growing number of published literature exploring or assessing its potential for several ailments. Mazunder et al. (2005) reported that the leaves and seeds are used in the Ayurvedic system of medicine to treat leprosy, ringworm, flatulence, colic, dyspepsia, constipation, cough, bronchitis and cardiac disorders. They added that the leaves also have some antifungal properties because of chrysophanic acid–9-anthrone (Acharya et al., 1975 as cited by Mazunder et al., 2005), whereas, the seeds have antibacterial properties due to phenolic compounds (Hatano et al., 1999 as cited by Mazunder et al., 2005). Tzeng et al. (2013) investigated

Table 1:
Phenotypic diversity estimates(H') of S. tora plants in situ in Bukidnon as per SSWDI as phenotyped on dif- ferent seasons

Plant Trait	December 2009 to January 2010 (n=12)	September 2009 to October 2010 (n=10)	December 2012 to January 2013 (n=13)
Growth stage(s)	Late reproductive stage to senescence	Vegetative stage to early pod development	Late vegetative stage
Plant height (cm)	0.93[H]	0.88[H]	0.67[H]
Stem diameter (cm)	-	0.64[M]	-
Number of primary branches/plant	0.74[M]	0.80[H]	0.92[H]
Number of nodes/plant	-	0.72[M]	-
Leaf length (cm)	-	-	0.82[H]
Leaf width (cm)	-	-	0.62[H]
Leaf area (cm^2)	0.87[H]	0.66[M]	0.78[H]
Leafiness	-	-	0.47[H]
Root nodulation	0.00I	0.00[I]	0.00[I]
Number of mature podes per plant	0.87[H]	-	-
Number of seeds per pod	0.79[H]	-	-
Weight of 100 seeds (g)	0.85[H]	-	-
Percent crude protein (seeds)	0.93[H]	-	-
Percent crude protein (young leaves)	-	-	0.79[H]
Percent crude protein (mature leaves)	-	-	0.81[H]
Seed coat color	0.68[M]	-	-
Seed coat texture	0.31[L]	-	-
Seed coat glossiness	0.42[L]	-	-
Mean H'			

H (high variability); M(moderate variability); L(low variability); I(invariant, no variant), n(number of ecotypes characterized in rats and reported the potential of seed extracts to alleviate high-fat diet-induced non-alcoholic fatty liver. Sreelakshmi and Abraham (2016) using Sprague Dawley pup rats reported that *C. tora* leaves could modulate selenite cataract by enhancing antioxidant status and preventing cytoskeletal protein loss in their lenses.

Ecotypic diversity of *in situ* plants

There is ecotypic diversity of the natural populations of *S. tora* in Bukidnon as per SSWDI (Table 1) based on their phenotypes. In three separate assessment of *in situ* populations at different stages of growth, four common parameters were measured. Moderate to high variability were estimated for plant height, number of primary branches per plant, and leaf area. However, root nodulation was invariant since all three surveys confirmed the non-nodulating habit of *S. tora*, as reported by Allen and Allen (1976, p. xxiii) for *Cassia* species. Other quantitative plant traits phenotyped only once were estimated to have moderate to high variability. PCP of seeds, young and mature leaves were all highly variable. Three qualitative seed traits (seed coat color, texture and glossiness) were poorly or moderately variable, as these are usually consistent across environments.

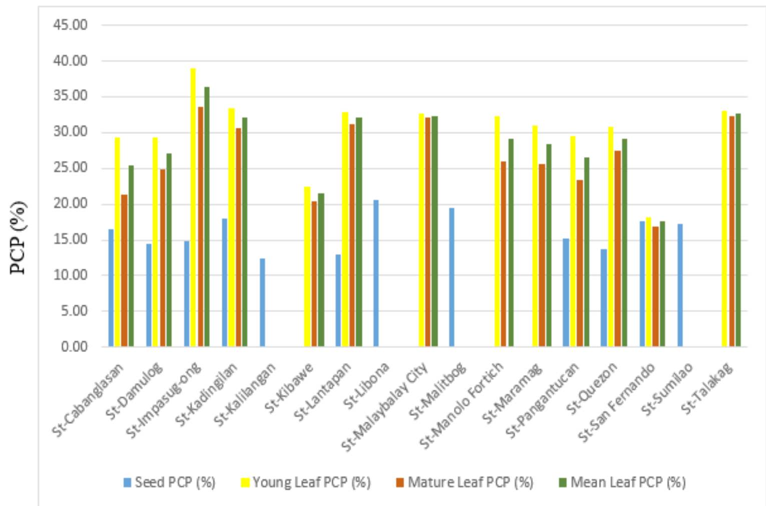
H' is an estimate of the magnitude of allelic richness of a plant trait within a population or in a set of germplasm (Shannon & Weaver, 1949). Hence, the presence of adequate variation (moderate to high) could allow selection for the most desirable ecotypes based on trait(s) of interest either for the immediate promotion of *S. tora* to become a more important or popular species, or for use in a crop improvement program to further refine some ecotypes prior to wider commercial use.

If *S. tora* is to be optimally used as food and forage crop, ecotypes that are taller, have more primary branches, leafier, with more leaflets and higher leaf PCP would be most desirable. In India, Mazumder et al. (2005) reported that *S. tora* could grow from 30.00-39.00 cm high whereas, Pawar and D'mello (2011) reported 30.00-90.00 cm range in height. In this investigation, mean height of *in situ* plants at different stages of growth ranged from 47.00-105.00 cm on December 2009 to January 2010 (late reproductive to senescence), 104.00-162.00 cm on September to October 2010 (vegetative stage to early pod development), and 13.00-38.00 cm on December 2012 to January 2013 (late vegetative stage).

Ecotypic diversity of *S. tora* in Central India was also reported by Tilwari et al. (2016) although based on molecular data. They estimated the genetic diversity of 15 accessions of *C. tora* from different agro-climatic zones of Madhya Pradesh. Fresh leaves were collected from *in situ* plants and processed for genotyping using six polymorphic RAPD primers. They reported that such accessions were genetically diverse based on the range of 0.23 – 0.65 Jaccard's similarity coefficients. *C. tora* is valued for herbal formulations hence, its genetic diversity and *in situ* conservation are critical to India.

Protein concentration of seeds and leaves of *in situ* plants in Bukidnon

Bulked seeds collected from *in situ* plants from each of 12 locations surveyed from December 2009 to January 2010 were analyzed for PTN used to estimate for PCP. Separate samples of young and mature leaves from *in situ* plants collected from each of 13 locations from December 2012 to January 2013 were also submitted for proximate analysis of PTN.



Senna tora ecotypes

Figure 3. Percent crude protein (PCP) of seed and leaf samples from i*n situ* population of *S. tora* ecotypes in Bukidnon

Table 2:
Mean comparison of S. tora ecotypes prior to imposition of stress at 13 DAT based on Tukey's HSD

Senna tora Ecotype	Class	Seeding Height (cm)	Leaflet Length (cm)	Leaflet Width(cm)	Leaflet area (cm^2)	Number of leaves per plant	Number of leaflets per plant
St-Impasug-ong	H	10.06^{cd}	2.03^{bc}	1.19^{ab}	1.86^{bcd}	2.00^{ab}	11.61^{b}
St-Kadingilan	H	11.80^{ab}	2.21^{ab}	1.27^{ab}	2.29^{abc}	2.17^{ab}	12.61a^{b}
St-Lantapan	H	9.61^{cd}	2.04^{b}	1.16^{ab}	1.80^{cd}	2.00^{ab}	11.69^{b}
St-Malaybalay City	H	10.58^{bc}	2.23^{ab}	1.24^{ab}	2.12^{abc}	2.11^{ab}	12.44^{ab}
St-Talakag	H	8.92^{d}	1.76^{c}	1.12^{b}	1.57^{d}	1.97^{b}	11.67^{b}
St-Cabanglasan	I	11.04^{bc}	2.30^{ab}	1.26^{ab}	2.35^{ab}	2.14^{ab}	12.53^{ab}
St-Damulog	I	12.63^{a}	2.34^{a}	1.31^{a}	2.40^{a}	2.28^{ab}	13.22^{ab}
St-Pangantucan	I	11.75^{ab}	2.12^{ab}	1.24^{ab}	2.22^{abc}	2.33^{a}	13.92^{a}
St-Kibawe	L	10.32^{bcd}	2.13^{ab}	1.19^{ab}	1.98^{abcd}	2.06^{ab}	11.92^{b}
St-San Fernando	L	10.76^{bc}	2.19^{ab}	1.24^{ab}	2.08^{abcd}	2.19^{ab}	12.24^{ab}
Probability Value (p)		<0.0001	<0.0001	0.0213	<0.0001	0.0082	0.0082
CV (%)		9.48	8.61	8.81	16.48	10.61	10.25

PCP(percent crude protein), H(high PCP), I(intermediate PCP), L(low PCP), DAT(days after transplanting). Means within columns with a common letter are not significantly different based on Tukey's HSD at 0.05 level of probability.

Results are shown in Figure 2.

Mungbean (*Vigna radiata* L.) is the most common food legume in the country. Dahiya et al. (2015) reviewed various papers and summarized that on average, PCP of mungbean seeds was 23.80% with a range of 14.60 to 32.60%. In contrast, PCP of *S. tora* seeds collected *in situ* from Bukidnon only had 12.40-20.46%. St-Libona recorded the highest numerical estimate at 20.46%. Pawar and D'mello (2011) reported that in India, seed protein concentration of *S. tora* was about 23.20%. However, PCP of young and mature leaves of *in situ* plants of Bukidnon ecotypes were higher at 18.18-39.02% and 16.94-33.68%, respectively. St-Impasug-ong had the highest numerical PCP estimates for young and mature leaves.

Either the seeds or leaves of *S. tora* would make it a valuable protein crop for food or feed especially that it grows ubiquitously in the province, and perhaps in the whole country. Some locals have indeed utilized young leaves as vegetable and leaves (regardless of age) as feed for household livestock (swine). However, *in situ* populations of *S. tora* are often left undisturbed because it may be unpalatable when eaten raw by grazing animals. According to Mazumder et al. (2005), its leaves although smooth are slightly bitter.

Potential resilience to drought and waterlogging stresses at vegetative stage

The *S. tora* ecotypes were phenotyped before the imposition of stress at 13 DAT, immediately after stress (29 DAT) and after one week of recovery from stress (36 DAT). Table 2 shows data for six traits at 13 DAT. Ecotypes highly differed for seedling height; leaflet length, width and area; number of leaves; and number of leaflets as per ANOVA. Grown *ex situ* under

Table 3:
Means of plant traits of 10 ecotypes under each water regime at 29 DAT (after 16 days of stress imposition).

Trait	Normal	Drought	Waterlogged
Plant height (cm)	20.48^{a}	17.88^{b}	14.45^{c}
Leaflet length (cm)	3.27^{a}	2.91^{b}	1.95^{c}
Leaflet witdth (cm)	1.84^{a}	1.62^{b}	1.08^{c}
Leaflet area (cm^2)	6.24^{a}	4.87^{b}	2.13^{c}
Number of leaves per plant	5.40^{a}	4.80^{b}	3.40^{c}
Plant stress tolerance	5.00^{a}	2.37^{b}	0.77^{c}

Means within columns with a common letter are not significantly different based on Tukey's HSD at 0.05 level of probability

Table 4:
Interaction between water regimes and ecotypes for number of leaflets per plant at 29 DAT

***Senna tora* Ecotype**	**NUMBER OF LEAFLETS PER PLANT**		
	Normal	**Drought**	**Waterlogged**
St-Cabanglasan	35.50$^{ab\ x}$	31.00$^{a\ x}$	23.20$^{a\ y}$
St-Damulog	35.50$^{ab\ x}$	28.20$^{a\ y}$	18.60$^{a\ z}$
St-Impasug-ong	27.60$^{bc\ x}$	28.20$^{a\ x}$	20.10$^{a\ y}$
St-Kadingilan	34.30$^{abc\ x}$	30.60$^{a\ xy}$	26.30$^{a\ y}$
St-Kibawe	34.00$^{abc\ x}$	29.80$^{a\ x}$	21.30$^{a\ y}$
St-Lantapan	24.80$^{c\ xy}$	27.20$^{a\ x}$	20.20$^{a\ y}$
St-Malaybalay City	27.40$^{bc\ x}$	30.40$^{a\ x}$	19.60$^{a\ y}$
St-Pangantucan	43.90$^{a\ x}$	28.90$^{a\ y}$	27.00$^{a\ y}$
St-Talakag	28.20$^{bc\ x}$	25.80$^{a\ xy}$	19.40$^{a\ y}$
St-San Fernando	27.40$^{bc\ x}$	25.10$^{a\ x}$	23.80$^{a\ x}$
P value (Stress, A)	<0.0001		
P value (Ecotype, B)	<0.0001		
P value (AxB)	0.0322		
Coefficient of variation (%)	14.25		

Means within the same column with common letters (a,b or c) and within the same row with common letters(x,y or z) are not significantly different based on Tukey's HSD at 0.05 level of probability

Musuan conditions, results confirm that phenotypic variation among the ecotypes as observed *in situ* was not just due to differences in environment but genetic as well.

After 16 days of stress (29 DAT), means of ecotypes for plant height, leaflet length, leaflet width, leaflet area, number of leaves per plant, and plant stress tolerance under each water regime showed similar patterns of variation (Table 3). Those under normal conditions had the highest values, then those under drought, with waterlogged plants showing the least. In general, ecotypes were affected, and therefore, susceptible to both drought and waterlogging at early vegetative stage for 16 days. However, ecotypes were mostly affected by waterlogging. Ecotypes under drought were moderately sensitive (2.37) whereas, waterlogged plants were highly sensitive (0.77) based on the scale of 1.00 for highly sensitive and 6.00 for highly tolerant (Jamago, 2017).

S. tora ecotypes across water regimes at 29 DAT also differed for the above traits (data table no longer shown). St-Pangantucan was tallest (21.30 cm), had the widest leaflets (1.73 cm), the biggest leaflets based on leaf area (5.85 cm^2), and the most leaf count per plant (5.70). St-Kadingilan had the longest leaflets (3.11 cm). In contrast, St-Talakag was the shortest and had the least leaf count per plant. St-Lantapan had the shortest and narrowest leaflets, and consequently the smallest leaflets. Nonetheless, means of plant stress tolerance were comparable among ecotypes, i.e. from 2.22 to 3.33 that are qualified as sensitive to moderately sensitive.

On the other hand, number of leaflets per plant at 29 DAT showed significant interaction between the two factors (Table 4). Plants have varied and complex responses to water stress which can be combinations of stress avoidance and tolerance (Chaves et al., 2002). Reducing the number of photosynthetic organs that require an adequate amount of water can be one of the adaptive changes to keep the water balance right. Results suggest that St-Pangantucan was comparably sensitive to both stresses whereas, St-Damulog was sensitive to both stresses but more sensitive to waterlogging. Five ecotypes (St-Cabanglasan, St-Impasug-ong, St-Kadingilan, St-Kibawe, St-Malaybalay City, and St-Talakag) were

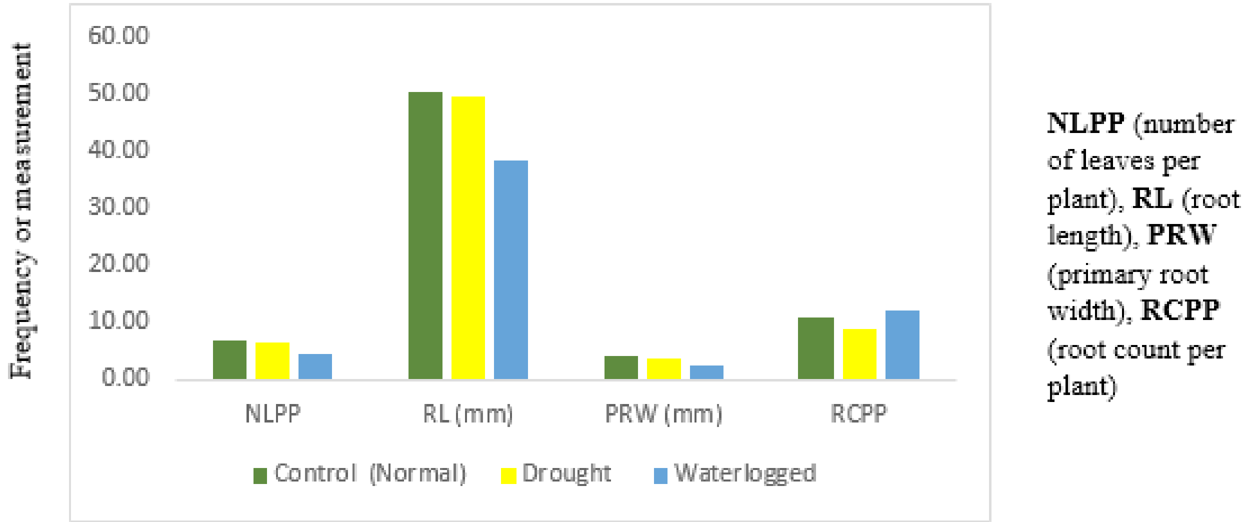


Figure 4. Means of plant traits of 10 ecotypes under each water regime at 36 DAT

tolerant to drought but sensitive to waterlogging. Lastly, St-Lantapan and St-San Fernando were tolerant to both stresses having comparable number of leaflets per plant with those under normal conditions. These two ecotypes were 'average performers' under each water regime as they recorded average measurements and showed consistent average performance in normal, drought and waterlogged conditions.

At 36 DAT, ecotypes under drought were able to recover and developed comparable number of leaves, root length and root width as the normal plants (Figure 4). Waterlogged plants, however, had comparable root count as the normal plants because of the development of adventitious roots above the soil. These adventitious roots allowed the ecotypes to either minimize hypoxia or prevent anoxia, which are

Table 5:
Mean root length and root count of ecotypes under each water regime, and across water regimes at 36 DAT

Senna tora Ecotype	ROOT LENGTH (cm)				ROOT COUNT PER PLANT			
	N	D	W	Mean	N	D	W	Mean
St-Cabanglasan	50.67	43.58	39.42	44.56^{ab}	13.00	8.80	13.20	11.70^{ab}
St-Damulog	55.83	55.08	41.58	50.83^{ab}	12.20	6.50	14.30	11.00^{ab}
St-Impasug-ong	53.42	49.75	42.42	48.53^{ab}	10.20	7.80	10.30	9.40^{ab}
St-Kadingilan	48.33	48.92	44.08	47.11^{ab}	10.30	8.70	15.50	11.50^{ab}
St-Kibawe	60.58	45.33	37.58	47.83^{ab}	11.70	8.70	11.20	10.50^{ab}
St-Lantapan	50.25	56.83	35.00	47.36^{ab}	9.70	10.50	14.00	11.40^{ab}
St-Malaybalay City	40.58	56.25	40.33	45.72^{ab}	10.50	9.70	9.50	9.90^{ab}
St-Pangantucan	60.75	54.92	47.24	54.31^{a}	14.30	9.50	14.20	12.70^{a}
St-San Fernando	45.38	46.00	33.42	41.60^{bc}	9.70	10.50	9.30	9.80^{ab}
St-Talakag	38.83	39.25	22.33	33.47^{c}	8.20	8.50	9.00	8.60^{b}
Mean	50.46^{a}	49.59^{a}	38.34^{b}		10.90^{a}	8.90^{b}	12.10^{a}	
P value (Stress, A)				<0.0001				0.0001
P values (Ecotypes, B)				<0.0001				0.0485
P value (AxB)				0.1420				0.1527
CV(%)				15.14				23.98

DAT (days after transplanting, N(normal water conditions), D(drought), W(waterlogged).
Means in the same column with the same letter are not significantly different as per Tukey's Test at 0.05 level of probability

mechanisms for tolerance against excessive moisture at the root zone.

At 36 DAT after one week of recovery from stress, two plants per replication were sampled to characterize root traits. Root length and root count per plant varied among the water regimes and among the phenotypes as per ANOVA, but interaction was not significant (Table 5). Ecotypes had significantly reduced root length after waterlogging (38.34 cm), but those in normal conditions (50.46 cm) and subjected to drought (49.59 cm) were comparable.

These results suggest that ecotypes were more sensitive to waterlogging and may have potential tolerance to drought at early vegetative stage. For ecotypes across water regimes, longest roots were recorded for St-Pangantucan (54.31 cm) whereas, the shortest roots were by St-Talakag (33.47 cm). However, these ecotypes were comparable with other ecotypes. For root count per plant, waterlogged plants had the highest root count (12.10) due to presence of adventitious roots but was comparable to plants under normal conditions (10.90). Those that suffered drought had the least with 8.90. Among the ecotypes across water regimes, St-Pangantucan had the highest root count (12.70) whereas, St-Talakag had the least (8.60).

Ecotypes subjected to drought that have comparable performance with plants under normal conditions may be considered water spenders as part of their drought avoidance mechanism. They could optimize water uptake, grow more roots, longer roots, more root hairs, or enhance hygrotropism. King et al. (2009) reported that in Salvia officinalis, lateral roots were developed in the upper part of the root system in response to five days of hypoxia to survive. Ayi et al. (2016) concluded that in Alternathera philoxeroides, its adventitious roots developed upon submergence were capable of harvesting oxygen from ambient water. Consequently, this allowed the plant to reduce the detrimental effect of oxygen deficiency, enabling the efficient use of carbohydrates, and delaying plant senescence. Ho et al. (2005) and Pinheiro et al. (2005) discussed that crops or genotypes with more capability to survive drought stress are those that proliferate their roots deeper in the soil.

At 36 DAT, plant height showed significant interaction at 36 DAT (Table 6). Based on Tukey's test of means on recovery in plant height, St-

Table 6:
Interaction of 10 S. tora ecotypes and water stresses of plant height and leaflet count per/plant at 36 DAT

Senna tora Ecotype	Plant Height (cm)		
	Normal	Drought	Waterlogged
St-Cabanglasan	29.13 abc x	25.03 a x	16.17 a y
St-Impasug-ong	23.02 bcd x	24.09 a x	14.14 a y
St-Kadingilan	25.70 abcd x	24.64 a x	22.17 a x
St-Kibawe	28.20 abcd x	22.40 ab y	16.15 a z
St-Lantapan	19.30 d xy	22.96 ab x	14.72 a y
St-Malaybalay City	22.50 bcd x	26.71 a x	14.86 a y
St-Pangantucan	33.29 a x	25.32 a y	19.00 a z
St-Damulog	29.68 ab x	23.23 ab y	17.02 a z
St-San Fernando	20.09 cd xy	22.94 ab x	15.38 a y
St-Talakag	21.62 bcd x	14.50 b y	13.15 a y
P value (Stress, A)	<0.0001		
P value (Ecotype, B)	<0.0001		
P value (AxB)	0.0205		
Coefficient of Variation (%)	15.87		

Means within column with common letters (a, b, or c) and within row with common letter (x, y, or z) are not significantly different based on Tukey's HSD at 0.05 level of probability.

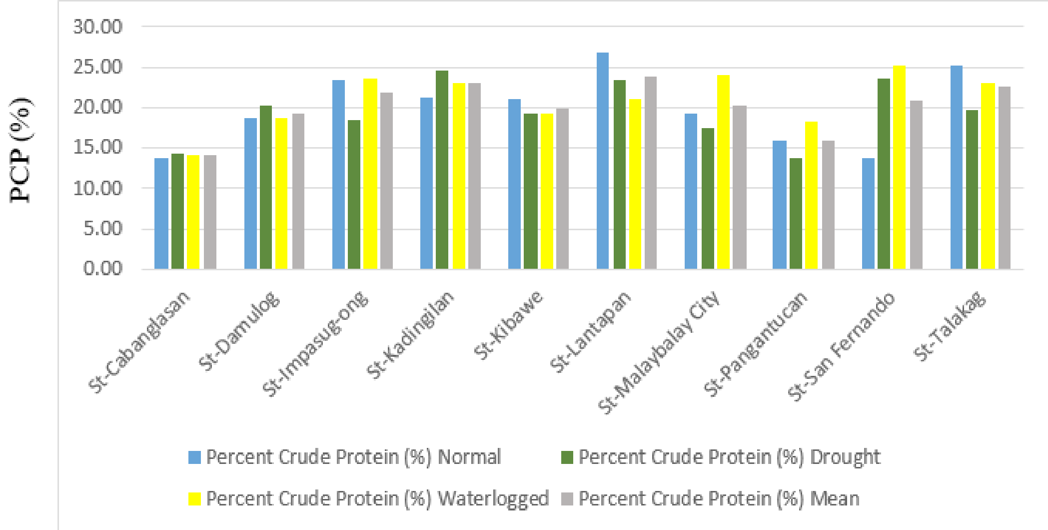


Figure 5. Percent crude protein (PCP) of seeds of 10 S. tora ecotypes subjected to drought and waterlogging for 16 days at vegetative stage

Kadingilan and St-Lantapan were tolerant to both stresses. These two had comparable height under normal conditions and after one week recovery from drought and waterlogging stresses, suggesting tolerance based on the resumption of normal vertical growth through cell division and elongation. St-Impasug-ong, St-Malaybalay City, St-Cabanglasan, and St-San Fernando were drought-tolerant but waterlogging-sensitive. St-Talakag was sensitive to both stresses, whereas, St-Pangantucan, St-Damulog, and St-Kibawe were sensitive to drought but more sensitive to waterlogging.

Resilience of S. tora ecotypes stressed at vegetative stage assessed through recovery is shown in other measured traits that did not vary as per ANOVA. Days to flowering did not differ among water regimes, among ecotypes and no interaction was detected. Days to flowering ranged from 154.37 (drought) to 155.81 d (waterlogged). Plants under normal condition flowered at 155.03 d. Among ecotypes, days to flowering ranged from 148.56 d (St-Kadingilan) to 161.58 d (St-Damulog). Similarly, duration of flowering did not differ for each factor and interaction was not significant. Ecotypes flowered for about a month. Means ranged from 31.23 d (drought) to 32.99 d (waterlogged). Plants under normal condition flowered for 32.13 d. Among ecotypes, duration of flowering ranged from 29.20 d (St-Damulog) to 34.67 d (St-Talakag).

At maturity, seeds were inadequate for analysis of PCP per replication and were not statistically analyzed. However, Figure 5 shows the PCP estimates of bulked seeds per ecotype per water regime. Under the water regimes, mean seed PCP (SPCP) of 10 ecotypes ranged from 19.49% (drought) to 21.08% (waterlogged). Plants under normal conditions had 19.92%. Numerically, St-San Fernando (25.30%) and St-Kadingilan (24.66%) had the highest SPCP after 16 days of waterlogging and drought at vegetative stage, respectively. Among ecotypes across water regimes, mean SPCP ranged from 14.09% (St-Cabanglasan) to 23.77% (St-Lantapan). Similarly, Pant et al. (2014) who subjected plantlets of two Cassia species to temperature stress from 30oC to 44oC for 16 h, reported an increase in the total protein of C. tora at 42oC. Accordingly, this tolerance to increased temperature was probably due to an increase in various osmolytes and an efficient antioxidant system. In this study however, the SPCP estimates still need to be validated using adequate seed samples.

CONCLUSIONS AND RECOMMENDATIONS

Results of these investigations show the phenotypic diversity of S. tora in Bukidnon both in situ and ex situ, and its potential to be also promoted as a food, feed, and medicinal crop in the country. A thorough and wider survey could probably record more uses of this species by the locals. Nonetheless, selection can be made to identify the most desirable ecotypes either for immediate use to commercialize or for further refinement in breeding programs.

However, additional biochemical studies are needed to ascertain its importance for food, feed, and medicine so that it could be well-utilized like in other countries. Its value and importance could increase especially in the midst of a changing climate. In general, results suggest that some ecotypes of S. tora when exposed to drought or waterlogging stress at early vegetative stage for 16 days have some mechanisms of tolerance. Such stress tolerance mechanisms include development of adventitious roots and growth recovery after when normal moisture conditions are restored. Perhaps, it can also become a cover crop encouraged and endorsed for uncultivated farmlands and other marginal areas.

ACKNOWLEDGEMENT

We thank the local peoples of Bukidnon who shared their knowledge and everyone who assisted in the series of studies.

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