ISSN : 2012 0060

S&T SCIENCE & TECHNOLOGY JOURNAL

VOL. 8 | 2018 ISSUE

SCIENCE AND TECHNOLOGY JOURNAL

Official Scientific Refereed Journal of the Mariano Marcos State University

Vol. VIII 2018 ISSUE ISSN: 2012 0060

The S&T Journal is a semi-annual refereed publication for multi-disciplinary research studies. It features articles advancing the knowledge of natural and applied sciences, trade and industry, health and environment, education, socio-economics, information technology, engineering, and other allied fields.

Published by: Mariano Marcos State University
City of Batac 2906 Ilocos Norte
Tel. (63) (077) 600-0459
email address: op@mmsu.edu.ph; SnTjournal@gmail.com
Printed: 2018

S&T

SCIENCE & TECHNOLOGY JOURNAL

VOL. 8 | 2018 ISSUE

TABLE OF CONTENTS

INFORMATION TO AUTHORS

The Science and Technology Journal is a semi-annual multi-disciplinary journal published by the Mariano Marcos State University. It features original and unpublished research papers including theses/dissertations advancing the knowledge of natural and applied sciences, trade and industry, health and environment, education, socio-economics, information technology, engineering, and other allied fields.

Articles accepted are those outputs of research studies conducted within the last five years immediately preceding the publication date of a journal issue. Submitted papers are read and evaluated by a technical review board composing of subject matter specialists in the different fields of specialization. The selected papers undergo blind-refereeing by respective specialists.

Manuscript Preparation

1. Articles should not be longer than 30 pages including tables, figures, references, and abstracts. It should be typed double-spaced on A4 paper size using only one sanscript font (e.g. Arial).
2. Organize the article with the following major parts 1) **title** (typed in a separate page with the author/s and contact information and indicating author for correspondence); 2) **abstract** (with keywords just after it); 3) **introduction** (includes brief background of the study, statement of the problem and its importance, a short survey of relevant literature, and the research objectives); 4) **methodology** (includes the locale of the study, the research design, the variables of the study, including the theoretical/ conceptual framework, data gathering procedures, and statistical analysis); 5) **results and discussion**; 6) **conclusions and recommendations**; and 7) **literature cited .**
3. Illustrations, figures, and tables should be placed just after they were cited. They should be numbered with arabic numerals and should carry brief descriptive titles.
    - Tables should have at least three columns. Columns that show no significant variations should be omitted.
    - Titles should be clear and column headings should be brief with units of measurements in parentheses.
    - Only the first letter of the first word of titles and headings should be capitalized; the rest should be presented in lower case unless in the case of proper nouns; and no period should be placed at the end of titles. Type size of tables should not be reduced to accommodate data.
    - Symbols and abbreviations should be defined below each table.
4. Figures/illustrations include line drawings, photographs, and computer plots. Magnification of figures (if needed) should be given by scale. The size should not exceed a full manuscript page. Photographs should be submitted in *jpeg*, *tif*, or *png* format stored in a CD with accompanying captions.
5. All pages, except the first page, should be numbered at the bottom center of the page, including those with tables and figures.
6. Footnotes in the text should be avoided. Ancillary information should appear in the text set off in parenthesis.

7. The International System or metric units of measurement should be used. The following abbreviations are acceptable: h, min, s, yr, mo, wk, km, m, cm, mm, kg, g mg, mL, etc. without periods. Use L for liter and % instead of percent. Designate temperature as in 27°C. For names of months, use three letters without the period as “Jan, Mar, Apr,” etc. Symbols, abbreviations, and acronyms should be defined when they are used first. Abbreviate units of measurement only beside numerals otherwise, spell out the units. Write the unit and numeral without space (4m, $15m^2$). For numbers, write out one to nine unless they are followed by unit of measurement (e.g., two species, 3cm). Day, month, and year should be written as “11 May 2006.”

Submission of Manuscript

1. Authors are required to submit to the Editorial Board a Certification of Originality/ Unpublished Work and a Confirmation of Consent for Publication.
2. Submit electronically prepared manuscripts using Microsoft Word. Two hard copies should accompany the soft copy.
3. Send manuscript to: Office of the Director, R&D Directorate, CRL Building, Mariano Marcos State University, City of Batac, Ilocos Norte for the hard copies. The soft copy may be submitted personally to the Managing Editor or send via e-mail: SnTjournal@gmail.com

Science and Technology Journal ISSN: 2012 0060
Vol. VIII 2018 Issue

EFFECTS OF INDOLE BUTYRIC ACID TREATMENT ON THE ROOTING AND GROWTH PERFORMANCE OF THE WILDLINGS OF TWO DIPTEROCARP SPECIES

Sergia P. Garma and Charito L. Samsam*

ABSTRACT

The use of wildlings as planting stock is usually constrained by root damage stress and low recovery in the nursery, thus, rapid root initiation is necessary to reduce the effect of transplanting shock. For this purpose, two separate experiments were conducted to determine the Indole Butyric Acid (IBA) concentration and dipping time on the wildlings' survival rate, root growth potential, growth characteristics and seedling quality index (SQI) of two dipterocarp species, *Anisoptera thurifera* (Blanco) Blume and *Hopea plagata* (Blanco) S. Vidal. The experimental treatments: IBA concentration (0, 50, 100, and 150 ppm) and dipping duration (10, 20 and 30 seconds) were applied to the experimental wildlings following a Randomized Complete Block Design (RCBD) in three replicates. Treatment effects were evaluated using ANOVA. Where F-test showed significant results, treatments were further compared using $HSD_{0.05}$.

In general, the application of 50ppm IBA enhanced the survival rate, growth characteristics, root growth potential, and SQI of both species. At 100 and 150 ppm concentrations, these parameters showed declining trend in *A. thurifera* but not in *H. plagata* indicating that the former is more sensitive than the latter to IBA treatment. Significant interaction effect of IBA concentration and dipping time was observed on the following parameters: root biomass, length of longest roots, and SQI of *A. thurifera* and number of new roots of *H. plagata*. IBA concentration of 50 ppm was most appropriate for both species but dipping time should not be longer than 10 seconds for *A. thurifera* otherwise the performance of the wildlings are adversely affected. For *H. plagata*, 30 seconds dipping time showed the best result but shorter dipping time can be done with 100 and 150 ppm IBA concentrations.

Keywords: *Dipterocarp species, rooting hormone, wildlings root growth potential, wildling biomass, seedling quality index*

INTRODUCTION

Dipterocarps are considered the most valuable timber species, commercially and environmentally; hence, they are the major source of timber for domestic and commercial purposes. However, due to overexploitation and extensive harvesting, some species are already categorized as endangered. In addition, the regeneration of Dipterocarps and other timber species is hampered by the lack of seed materials brought about by its irregular flowering and fruiting characteristics and the short viability period of its seeds (Chechina, 2015).

One of the alternative sources of planting material to hasten the regeneration process is the use of wildlings. However, recovery of the collected wildlings in the nursery is very low (Gregorio *et al.*, 2010). This could be attributed to the disturbance or damage on the root system during uplifting, loss of water or stress during transport, and

**Corresponding Author Current Address: College of Agriculture, Food and Sustainable Development, Mariano Marcos State University, City of Batac, Ilocos Norte 2906 Philippines; email: sergia.p.garma@gmail.com*

the susceptibility of the young plant to diseases, thus, leading to early mortality. Furthermore, the ability to effectively enhance the immediate initiation of the root is critical to maintaining water balance and seedling establishment. Hence, to reduce the effect of transplanting shock, the seedlings must be provided with favorable conditions to initiate root growth, faster recovery, and survival.

Many studies have shown that auxins control the growth and development of plants, including root initiation and development (Sevik and Guney 2013). In addition, these studies have shown that the application of rooting hormone influences root initiation (Mobli and Baninasab, 2009). However, plant response to auxins varies with species and to the growing conditions they are exposed to.

The ability to absorb water is very critical in the development of bare root seedlings or wildlings. The quality and capability to survive under varied conditions depend upon the planting material's root growth potential (Davis and Jacobs, 2005 cited in Tsakaldimi, Ganatsas and Jacobs, 2013). Although auxins are widely used in plant propagation to stimulate and promote root initiation, their applicability to various provenance and other sources of planting materials is limited. IBA is an auxin that specifically enhances root formation and has been proven to increase plant growth (powergrown.com). For instance, in the study of Aminah et al. (1995), the application of 20µg IBA on single node cuttings of *Shorea leprosula* Miq., Sum. significantly enhanced the rate of root emergence and increased the number of roots that developed. For *Morus alba* L., stem cuttings treated with 1000, 2000, and 3000mg L^{-1} IBA exhibited higher rooting percentage, root number, and root length than the untreated ones (Husen *et al.*, 2015). Amminudin & Tahir (2006) also reported that the combined IBA and high humidity chamber (HHC) treatment increased the re-establishment success of *Parashorea malaanonan* (Blanco) Merr. wildlings in the nursery.

The study was conducted to evaluate the effects of IBA application and determine the ideal concentration of IBA and dipping duration that could enhance the rooting potential and growth of two dipterocarp species propagated through wildlings.

METHODOLOGY

Locale of the Study

The study was conducted at the Central Nursery of the Mariano Marcos State University, City of Batac, Ilocos Norte in May 2016 to December 2017. Two dipterocarp species, *A. thurifera* (Blanco) Blume and *H. plagata* (Blanco) S. Vidal, were considered in this study and experimental wildlings were collected from the secondary growth forest in Nueva Era, Ilocos Norte which lies between N 17° 53' 12" latitude to E 120° 40' 6.6" longitude. The potting medium used was a 2:1 mixture of OGS + river sand. The study area was provided with a black net to regulate the effect of environmental factors such as strong wind, excessive sunlight, and intense rainfall.

Research Design and Treatments

Separate experimental set-up was established for each species. In the absence of literature on the best concentration of IBA for these two species, a trial testing was done to develop the most appropriate IBA concentrations for investigation in this study.

For each set-up, two experimental variables were evaluated: IBA concentration and dipping duration with four and three levels, respectively. The IBA concentrations in ppm were 0 (no application), 50, 100, and 150, while the dipping durations were 10, 20, and 30 seconds. The experimental variables were applied to the experimental wildlings following a 4x3 factorial in RCBD in three replicates. There were 25 wildlings per experimental unit or a total of 900 seedlings in each set-up. Thus, to ensure uniformity or reduce variability in the physical conduct of the experiment to the minimum, RCBD instead of Completely Randomized Design was used although the study was conducted under nursery conditions.

Processing and Application of Treatments

The wildlings used in the study were mud-puddled and wrapped with banana leaf immediately after uprooting to keep the roots moist and minimize shock due to the disruption of the root system. The leaves and the long tap root of the wildlings were pruned using a sharp scissor to minimize transpiration. The wildlings were then sorted, and only wildlings of approximately the same height were considered. These were washed with tap water to remove the mud, followed by dipping in a container filled with fungicide for disinfection. After which, the wildling roots were soaked in IBA solution, following the concentration and dipping duration prescribed in the treatments.

Planting and Maintenance of Planting Materials

After the application of the treatments, the wildlings were potted immediately in 5”x7” polyethylene bags filled with OGS and river sand mixture at 2:1 ratio. The potted wildlings were arranged in a potting bed and covered with a chamber made of plastic sheet for two weeks. While inside the recovery chamber, the plants were watered twice a week and every day after the chamber's removal for one month. Weeding and spraying of insecticide were done as the need arises.

Data Gathered

The effect of the IBA treatment was assessed based on the following parameters: survival, growth attributes, root growth potential (RGP), and SQI. Growth attributes include plant height, stem diameter, root collar diameter, number of leaves, and shoot and biomass. RGP is an indicator of seedling quality. It is defined as the ability of the seedlings to initiate and elongate roots when placed in an environment favorable for root growth (Ritchie, 1985 cited in Tsakaldimi, Ganatsas, and Jacobs, 2013). In the study, RGP was evaluated based on the length of the longest root and the number of new roots. The SQI also referred as Dickson quality index developed by Dickson et al. (1960) cited in del Campo, Navarro, and Ceacero, (2010) was used taking into account the total dry matter, shoot height, stem base diameter, and shoot and root dry matter.

Data Analysis

The data gathered were subjected to analysis of variance (ANOVA) for RCBD. Where F-test showed significant result, treatment means were compared using Honestly Significance Difference (HSD) Test at 5% level of significance.

RESULTS AND DISCUSSION

Survival Rate

The concentration of IBA significantly affected the survival rate of both species (Table 1). However, dipping time or its interaction with IBA concentration did not affect survival of both species.

For *A. thurifera* wildlings, survival rate was enhanced by dipping them in 50ppm IBA but survival rate showed a declining trend at higher concentrations. IBA treatment at 50ppm concentration similarly enhanced the survival rate of *H. plagata* wildlings. Unlike *A. thurifera* wildlings, further IBA increment did not show adverse effect on the survival rate of *H. plagata.*

Growth Attributes

The concentration of IBA significantly affected all the growth attributes of *A. thurifera* wildlings (Table 2). The wildlings treated with 50ppm IBA exhibited better growth attributes than the untreated and

Table 1. Effect of IBA concentration and dipping time on the survival rate (%) of *A. thurifera* and *H. plagata* wildlings

TREATMENT	*A. thurifera*	*H. plagata*
IBA concentration (A) ppm	**	**
0	66.29 c	65.56 b
50	90.44 a	83.33 a
100	76.89 b	85.00 a
150	79.56 b	81.11 a
Dipping Time (B) sec	ns	ns
10	77.72	76.25
20	78.17	80.42
30	76.00	79.58
A x B	ns	ns
CV (%)	10.1	18.40

** - significant at 1% level
In a column and within the same factor, means followed by a common letter are not significantly different using $HSD_{0.01}$.

Table 2. Effect of IBA concentration and dipping time on the growth of *A. thurifera* and *H. plagata* wildlings

TREATMENT	HEIGHT cm	STEM DIA. (mm)	ROOT COLLAR DIA. (mm)	NUMBER OF LEAVES	SHOOT BIOMASS (g)	ROOT BIOMASS (g)
Conc. of IBA	**	**	*	**	**	**
0	15.52 b	3.02 b	2.84 b	5.29 b	0.44 c	0.14 c
50	17.83 a	3.22 a	3.00 a	6.11 a	0.63 a	0.25 a
100	16.62 b	3.08 b	3.04 a	6.07 a	0.55 b	0.19 b
150	16.78 b	3.10 b	2.96 b	5.48 b	0.57 b	0.20 b
Dipping Time	ns	ns	ns	ns	*	*
10 sec	16.58	3.14	2.98	5.94	0.59 a	0.21 a
20 sec	16.76	3.14	2.95	5.58	0.51 b	0.19 b
30 sec	16.72	3.04	2.96	5.69	0.53 b	0.18 b
A x B	ns	ns	ns	ns	ns	*
CV (%)	6.20	3.80	4.80	8.40	11.40	12.40

** - significant at 1% level
* - significant at 5% level
ns - not significant
In a column and within the same factor, means followed by a common letter are not significantly different using $HSD_{0.05}$.

those treated with IBA at concentrations 100 and 150ppm except on the root collar diameter and number of leaves where the effect of 50 and 100ppm concentrations did not differ with each other. On the other hand, dipping duration only showed significant effect on shoot and root biomass wherein values observed on 10 seconds dipping time was higher than either 20 or 30 seconds. A significant IBA concentration x dipping time interaction effect was observed on root biomass (Fig. 1). In general however, 50ppm concentration and 10 seconds dipping time showed the highest root biomass. At longer dipping time, root biomass was not significantly affected irrespective of the concentration of IBA.

IBA treatment also enhanced the growth characteristics of *H. plagata* with 50ppm concentration showing the best result

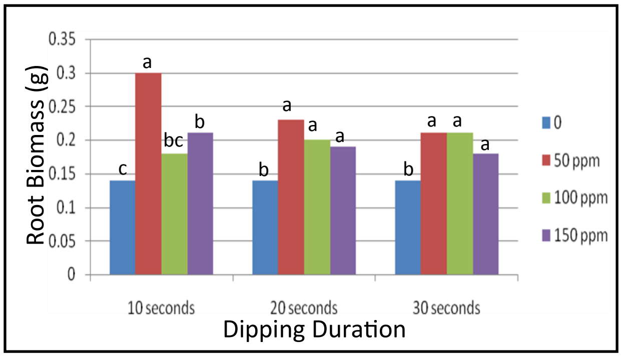

Fig. 1. Interaction effect of IBA concentrations and dipping duration on the root biomass of *A. thurifera* wildlings

Table 3). There was no significant advantage when the concentration was increased to 100ppm but a detrimental effect resulted when concentration was further increased to 150ppm.

Dipping time did not show significant effect on height, stem diameter, root collar diameter and shoot biomass. However, significant effect was observed on the number of leaves and root biomass where 20 and 30 seconds dipping time showed better effect than 10 seconds. Further, there was no significant interaction effect of IBA concentration and dipping time on the growth attributes of this species.

The enhancement in growth of both species was consistent with the result obtained from KHIRNI (*Manilkara hexandra ROXB*) seedlings cv. local wherein all the growth parameters were enhanced when applied with IBA. However, such was observed at a much higher concentration of 1000 ppm (Panchal, Parasana, Patel and Patel, 2014).

Table 3. Effect of IBA concentration and dipping time on the growth attributes of *H. plagata* wildlings

TREATMENT	HEIGHT cm	STEM DIA. (mm)	ROOT COLLAR DIA. (mm)	NUMBER OF LEAVES	SHOOT BIOMASS (g)	ROOT BIOMASS (g)
Conc. of IBA	**	**	**	**	**	**
0	14.53 c	1.58 c	1.78 b	2.44 c	0.46 c	0.14 c
50	16.89 a	2.06 a	2.05 a	3.44 a	0.69 a	0.24 a
100	16.27 a	1.91 a	2.00 a	3.33 a	0.60 a	0.22 b
150	15.65 b	1.80 b	1.87 b	2.89 b	0.58 b	0.19 bc
Dipping Time	ns	ns	ns	*	ns	*
10 sec	15.58	1.78	1.87	2.75 b	0.55	0.18 b
20 sec	15.98	1.85	1.93	3.08 a	0.59	0.19 b
30 sec	15.95	1.88	1.98	3.25 a	0.62	0.23 a
A x B	ns	ns	ns	ns	ns	ns
CV (%)	4.30	5.70	6.50	13.70	14.10	18.40

** - significant at 1% level
* - significant at 5% level
ns - not significant
In a column and within the same factor, means followed by a common letter are not significantly different using $HSD_{0.05}$.

Table 4. Effect of IBA concentration and dipping time on the root growth potential of *A. thurifera* and *H. plagata* wildlings

TREATMENT	LENGTH OF LONGEST ROOT (cm)		NUMBER OF NEW ROOTS	
	A. thurifera	*H. plagata*	*A. thurifera*	*H. plagata*
Conc. of IBA	**	**	**	**
0	14.04 b	11.14 b	21.24 b	12.56 c
50 ppm	16.23 a	13.32 a	29.68 a	19.17 a
100 ppm	16.23 a	13.61 a	29.31 a	18.28 b
150 ppm	16.17 a	13.05 a	28.60 a	16.50 c
Dipping Time	**	*	ns	**
10 sec	16.44 a	12.27 b	28.45	15.29 b
20 sec	15.41 b	12.98 ab	26.61	16.71 b
30 sec [a]	15.53 b	13.16 a	26.56	17.88 a
A x B	**	ns	ns	**
CV (%)	4.5	6.0	7.9	9.1

** - significant at 1% level
* - significant at 5% level
ns - not significant
In a column and within the same factor, means followed by a common letter are not significantly different using $HSD_{0.05}$.

Root Growth Potential

The IBA concentration and dipping time showed significant effect on the RGP of both species (Table 4). The length of longest root and the number of new roots of IBA treated wildlings irrespective of concentration were higher than the untreated except on the number of new roots of *H. plagata* where IBA concentration higher than 50ppm showed detrimental effect. A dipping time of 10 seconds resulted in the production of longer roots in *A. thurifera* and 20 seconds in *H. plagata*. For the production of new roots, dipping time failed to show significant effect on new root production in *A. thurifera* while 30 second dipping time enhanced formation of new roots in *H. plagata*.

Significant interaction effects of IBA concentration and dipping time were observed on the length of longest roots of *A. thurifera* (Fig. 2) and the production of new roots of *H. plagata* (Fig. 3). Regardless of dipping time, *A. thurifera* treated with IBA produced longer roots than the untreated ones but a longer dipping time showed detrimental effect at 150ppm IBA

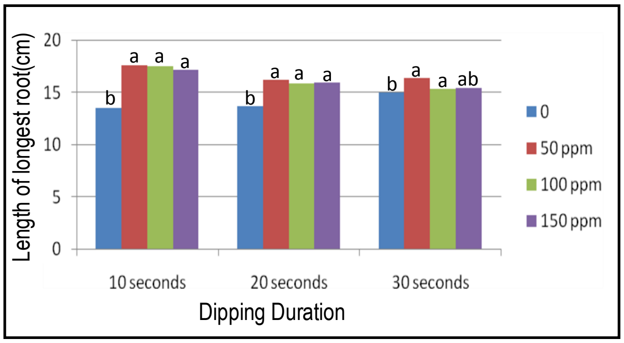

Fig. 2. Interaction effect of IBA concentrations and dipping duration on the length of longest roots of *A. thurifera*

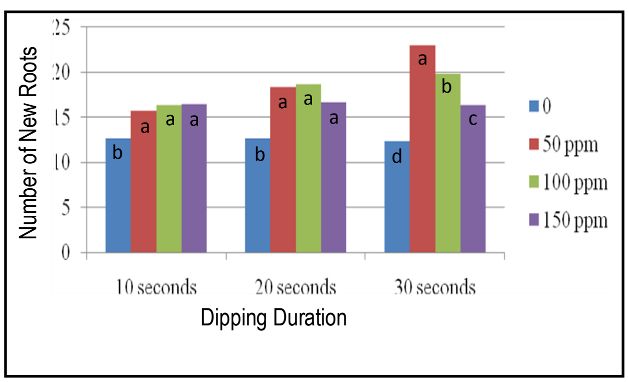

Fig. 3. Interaction of IBA concentrations and dipping duration on the number of new roots of *H. plagata* wildlings

concentration. On the other hand, more new roots were observed in *H. plagata* wildlings dipped in 50ppm IBA for 30 seconds. At higher IBA concentration, 10 and 20 seconds dipping time showed better result than 30 seconds. Since root growth is vital in establishing planting materials from wildlings and is very critical in their early recovery, the higher the RGP, the greater would be the plant's ability to absorb water and minerals. This is an important factor in enhancing planting stock vigor and survival rates (Corpuz, and Carandang, 2012). Furthermore, the production of new roots by the wildlings is essential in minimizing transplanting shock. The increased root access to soil water depends on new roots production and distribution and the root hydraulic conductivity (Mariotti, Maltoni, Jacobs and Tani, 2015). Ability to absorb water and minerals is an important indicator of planting stock vigor. Furthermore, the production of new roots by the wildlings is essential in minimizing transplanting shock. The increased root access to soil water depends on new roots production and distribution and the root hydraulic conductivity (Mariotti, Maltoni, Jacobs and Tani, 2015).

Seedling Quality Index

The SQI of both *A. thurifera* and *H. plagata* was increased by IBA application (Table 5). According to Ritchie (1984), the higher the value of SQI, the better is the seedling quality but literature indicating the minimum SQI value for different timber species in the tropics is still limited (Rosario, et al., 2012).

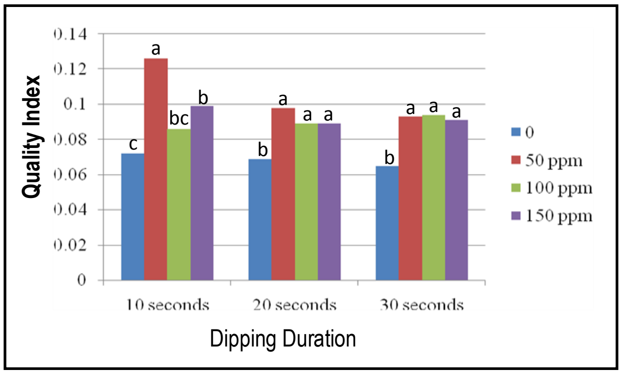

Fig. 4. Interaction effects of IBA concentrations and dipping *duration* on the quality index of *A. thurifera*

Table 5. Effect of IBA concentration and dipping time on the seedling quality index of *A. thurifera* and *H. plagata* wildlings

TREATMENT	SEEDLING QUALITY INDEX (SQI)	
	Anisoptera thurifera	*Hopea plagata*
Concentration of IBA	**	**
0	0.069 c	0.047 c
50 ppm	0.106 a	0.086 a
100 ppm	0.089 b	0.072 b
150 ppm	0.091 b	0.065 b
Dipping Time	*	*
10 sec	0.096 a	0.062 b
20 sec	0.086 b	0.065 b
30 sec	0.084 b	0.076 a
A x B	*	ns
CV (%)	11.1	16.1

** - significant at 1% level
* - significant at 5% level
ns - not significant
In a column and within the same factor, means followed by a common letter are not significantly different using $HSD_{0.05}$.

Generally, both species obtained higher SQI when these were treated with 50ppm IBA. The SQI values actually showed declining trend at higher concentration of 100 and 150ppm. In terms of dipping time, the SQI of *A. thurifera* was higher when dipped in IBA for 10 seconds than either 20 or 30 seconds. In contrast, IBA concentration and dipping time showed interaction effect on the SQI of *A. thurifera* (Fig. 4). IBA concentration of 50ppm and 10 seconds dipping time showed the best result. At longer dipping time (20 and 30 seconds), SQI did not differ among IBA concentrations.

CONCLUSION

Dipping wildlings of *A. thurifera* and *H. plagata* in various concentrations of IBA stimulated the production of longer roots and new roots resulting in better growth characteristics and higher survival rate of planting stocks of the two species. IBA concentration of 50ppm was most appropriate for both species. A 10-minute dipping time was most appropriate for *A. thurifera* while 30 seconds for *H. plagata*. Higher concentration of 100 and 150ppm and dipping time of 20 and 30 seconds were particularly detrimental to *A. thurifera*.

LITERATURE CITED

Aminah, H., Dick J.McP., Leakey, R.R.B. Grace, J. and Smith, R.I. (1995). Effect of IBA on Stem Cuttings of *Shorea leprosula*. Forest Ecology and Management. Vol.72:2 -3.p.199-206. https://science direct.com/ science/article/abs/pii/0378112794034615.

Aminuddin bin Mohamad and Jameri Tahir. (2006). Potential of wildlings of *Parashorea malaanonan* as Planting Stock. Vietnamese Academy of Forest Sciences. http://vafs.gov.vn/en/2006/05/ potential-of-wildlings-of-parashorea-malaanonan-as-planting-stock/.

Chechina, M. (2015). Sustainable management of dipterocarp forests in the Philippines. A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Forest Biology and Management. Department of Renewable Resources University of Alberta. 121pp.

Corpuz, O.S and Carandang, W.M. (2012). Effect of root growth potential, planting distance and provenance on the growth and survival of *Gmelina arborea* Roxb. *Asia Life Sciences* 21 (1) 1-18, 2012. The Asian International Journal of Life Sciences.

Davies, A.S. and Jacobs, D.F. (2005). Quantifying root system of quality nursery seedlings and relationship to outplanting performance. New Forest 30:295-311. Cited in Tsakaldimi, M, Ganatsas P. and Jacobs, D.F. 2013. Prediction of Planted Seedling Survival of Five Mediterranean Species Based on Initial Seedling Morphology. New Forests. Vol 44, Iss. 3 (May 2013):327-339.

del Campo, A.D., Navarro, R.M. and Ceacero, C.J. (2010). Seedling quality and field performance of commercial stocklots of containerized holm oak (*Quercus ilex*) in Mediterranean Spain: an approach of establishing a quality standard. New Forests (2010) 39: 19. https://doi.org/ 10.1007/s11056-009-9152-9.

Dickson, A.F., Leaf, A.L. and Hosner, J.F. (1960). Quality appraisal of white spruce and white pine seedling stock in nurseries. *Forestry Chronicle* Vol 36 No. 1 pp10-13. Cited in del Campo, A.D., Navarro, R.M. & Ceacero, C.J. 2010. Seedling quality and field performance of commercial stocklots of containerized holm oak (*Quercus ilex*) in Mediterranean Spain: an approach of establishing a quality standard. New Forests (2010) 39: 19. https:// doi.org/10.1007/s11056-009-9152-9.

Gazal, R.M., Blanche, C.A. and Carandang W.M. (2004). Root growth potential and seedling morphological attributes of Narra (*Pterocarpus indicus Willd*.) transplants. Forest Ecology and management 195 (2004) 259-266. www.elsevier.com/locate/ foreco. In Mariotti, B., Maltoni, A., Jacobs, D.F. and Tani A. 2015. Container effects on growth and biomass allocation in *Quercus robur* and *Juglans regia* seedlings, Scandinavian Journal of Forest Research, 30:5, 401-415.

Gregorio, N., Harrison, S., and Herbohn, J. (2010). The seedling nursery survey on Leyte Island, the Philippines. Annals of Tropical Research 32(2):1-14. Retrieved March, 2017.

Grossnickle, S.C. (2012). Why seedlings survive: Influence of plant attributes. New Forest (2012) 43: 711-738. https:// doi.org/10.1007/s11056-012-9336-6.

Husen, A., Iqbal, M.N., Sohrab, S.S. and Masresha, G. (2015). Effect of IBA on clonal propagation of mulberry (*Morus alba*) stem cuttings: Rooting and associated biochemical changes. Proceedings of the National Academy of Sciences: Biological Science Section 8. p. 161-166. https://linkspringer.com/article/ 10.1007/s40011-015-0597-7.

Mariotti, B., Maltoni, A., Jacobs, D.F. and Tani, A. (2015). Container effects on growth and biomass allocation in *Quercus robur* and *Juglans regia* seedlings, Scandinavian Journal of Forest Research, 30:5, 401-415, DOI:10.1080/02827581. 2015.1023352.

Mobli, M & Baninasab, B. (2009). Effect of indole butyric acid on root regeneration and seedling survival after transplanting of three Pistacia species. Journal of Fruit and Ornamental Plant Research Vol. 17/(1) 2009: 5-13. www.insad.pl/files/journal_pdf/ journal2009/vol17(1)2009.

Panchal, G.P., Parasana, J.S., Patel, S.R. and Patel, M.V. (2014). Effect of different growing medias and levels IBA on growth and development of Khirni (*Manilkara Hexandra* Roxb) seedlings Cv. Local. Global Journal of Bio-Science and Biotechnology. Vol. .3 (4) 2014: 379-383.

Ritchie, G.A. (1984). Assessing seedling quality. Pages 243-259 in Forest nursery manual: Production of bareroot seedlings (M. L. Duryea and T. D. Landis. eds.). Cited in Tsakaldimi, M, Ganatsas P. and Jacobs, D.F. 2013. Prediction of Planted Seedling Survival of Five Mediterranean Species Based on Initial Seedling Morphology. New Forests. Vol 44, Iss. 3 (May 2013):327-339.

Rosario, J.I., Tulod, A.M., Carandang, W.M. and Castillo A.S.A. (2012). Root growth potentials and morphological characteristics of *Jatropha curcas* L. seedlings from three provenances. MMSU Science and Technology Journal. Volume 2 (July-December 2012) pp 37-48.

Sevik, H. & Guney K. (2013). Effects of IAA, IBA, NAA and GA3 on rooting and morphological features of *Melissa officinalis* L. stem cuttings. The Scientific World Journal. Volume 2013 (2013) http:// dx.doi.org/10.1155/2013/909507.

Waheed, A., Hamid, H., Ahmad, F.M., Abbassi, A.S., Shah, A.H., Ahmad, N., Naheed, Z., Ali, H., and Khan, N. (2014). Effect of Indole Butyric Acid (IBA) on early root formation (Tomato "Sahil" Hybrid) Cuttings J. Mater. Environ. Sci. 6 (1) (2015) 272-279.

Science and Technology Journal
Vol. VIII 2018 Issue ISSN: 2012 0060

PERFORMANCE OF TRADITIONAL UPLAND RICE (*Oryza sativa*) VARIETIES IN RAINFED LOWLAND AREAS OF BATAC, ILOCOS NORTE

Araceli J. Badar and Menisa A. Antonio*

ABSTRACT

The role of traditional upland rice (TUR) in meeting household rice sufficiency in many upland communities is indispensable. However, growing them using slash and burn farming is restricted by the government due to its destructive effects on the environment. Thus, a two-year (2013-2014 WS) growth and adaptability trial involving 49 accessions and one registered check variety for rainfed lowland was conducted in the rainfed lowland areas of MMSU, Batac, Ilocos Norte. The study aimed to identify high-yielding and adaptable accessions in such ecosystem.

Four TUR's consistently out-yielded the check variety with yields ranging from 3.3 to 4.17 t ha^{-1} in both the 2013 and 2014 wet season cropping. These were accessions TUR 53, 72, 74 and 77. These have fertile spikelets, medium sized panicles, medium tillering capacity, medium to big seed size. These accessions were recommended for rainfed lowland cultivation.

Keywords: *traditional upland rice, growth performance, rainfed lowland ecosystem, rice sufficiency*

INTRODUCTION

Upland rice is one of the most popular cereal crops and plays a very important role in mountain peoples' lives. Like maize and cassava, upland rice is a main source of food for people. The life of ethnic minorities is closely linked with upland farming in general and upland rice cultivation in particular.

TUR is known for its quality and aromatic flavor, which is highly demanded as source of carbohydrates specifically for the Filipinos. These varieties have high demands in the market, thus requiring higher prices than the modern rice varieties. However, with technological advances and introduction of high-yielding varieties, these TUR were almost displaced in the system and area of cultivation was reduced.

According to Philippine's National Statistical Center (2004), upland rice yields an average of 1.7 t ha^{-1} versus 3.6 t ha^{-1} for wet season lowland rice. Because of its low yield, upland rice is generally considered to be unsuitable for intensive management practices aimed at high yields. However, the low yield of upland rice is largely a consequence of its production being limited to infertile or drought-prone uplands and low harvest index (HI) of traditional cultivars (George *et al.*, 2001).

In Ilocos Norte and most parts of the country, TUR is usually cultivated through

**Corresponding Author Current Address: Research Directorate Mariano Marcos State University, City of Batac, Ilocos Norte 2906 Philippines; email: celybadar@yahoo.com*

slash-and-burn in high mountainous areas despite prohibitions set by the government. In order to reduce the ecological hazards to the upland agro-ecosystem and forest resources brought about by slash-and-burn practice, less risk-prone areas such as rainfed lowland areas have to be explored for traditional rice cultivation, therefore enhancing the sustainability of upland rice production and the environment.

Rainfed lowland ecosystems are unirrigated, leveled, and bunded fields that have shallow flooding with rainwater (Mackill *et al.*, 1996 as cited by Haefele, 2009). These are agro-ecosystems characterized by fields that are flooded for at least part of the growing season. As mentioned earlier, TURs are grown in upland areas which are infertile and droughty. Knowing this as resilient crop, there should be no reason why TUR cannot be productively grown in rainfed lowland ecosystem given the appropriate accessions. It was in this context that this research was conducted.

METHODOLOGY

Locale of the Study

The study was conducted for two consecutive years, in 2013 and 2014 wet season (WS), at the MMSU Experimental Farm, City of Batac, Ilocos Norte. The experimental site is a rainfed lowland area with an elevation of 17.9m above mean sea level (masl) and situated at 18° 3' N latitude, and 120° 53' E longitude. Weather data during the two-year trial were gathered from the MMSU-PAGASA, Agrometeorological Station, MMSU, City of Batac. These varied particularly on the amount of solar radiation, distribution of rain events and occurrence of typhoons. Total rainfall from June to September was 1863.8mm in 2013 WS while 1420.6mm in 2014 WS. However, despite the high total rainfall in 2013, a relatively long interspersed dry spell occurred during the vegetative stage of the crop. Further, high rainfall occurred during the late part of August 2013 which coincided with the booting stage, and at mid-September during the peak of the reproductive phase (Fig. 1). A good rainfall pattern was observed during the 2014 WS from vegetative to early reproductive stages of the crop. Cyclones in both years occurred sporadically during the growing season. There were more tropical cyclones in 2014 (12) than in 2013 (10), most of which occurred in September and October, coinciding with the reproductive and grain ripening phases of the crop.

The temperature ranged from 23.94°C to 32.07°C (maximum) in 2013, and about 22.65°C to 31.92°C in 2014. These are within the maximum and minimum temperature requirements of rice (http://www.rice-trade.com/climatic-conditions-rice.html).

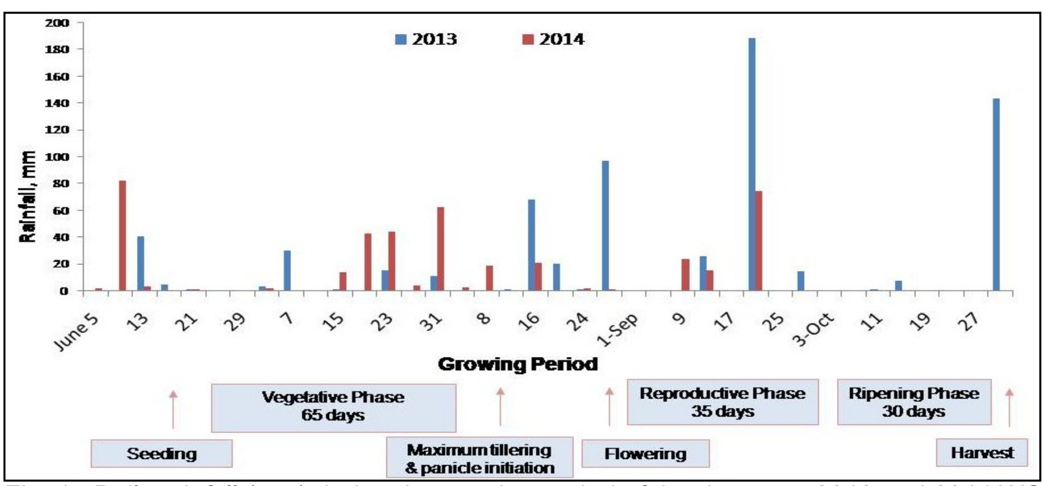

Fig. 1. Daily rainfall (mm) during the growing period of the rice crop, 2013 and 2014 WS

Experimental Design and Treatments

The research involved a field experiment of 49 TUR accessions and a registered variety for rainfed lowlands, NSIC Rc 146, as the check variety. It was laid out in Randomized Complete Block Design (RCBD) with 3 replications. Unit plot size was 9.0m^2 with 50cm distance between treatment plots. The accessions were numbered from 51 to 99 for identification.

Crop Establishment and Maintenance

Following the farmer's practice, about 3 to 5 seeds were dibbled per hill^{-1} with a distance of 20cm between hills and 30cm between rows. Resowing was done in hills with poor germination at 7 to 10 DAS. The recommended fertilizer of 90-60-60kg N-P2O5-K2O ha^{-1} was followed. All P and K and two-thirds of N were applied basally. The remaining N was top-dressed in 2 equal splits, during maximum tillering and at panicle initiation stages. Herbicide was sprayed before sowing. This was complemented with manual weeding during the crop's vegetative stage. The crop was not sprayed with any pesticide since pest infestation was not severe. The crop depended on rainfall except during long interspersed dry spells at critical growth stages especially during panicle initiation stage (50-60 DAS) where supplemental irrigation from a shallow tube well was applied twice a week.

Data Gathering Procedures

Agronomic data such as plant height, number of tillers hill^{-1}, panicle length and spikelets fertility were gathered using 10 sample plants per unit plot. Spikelet fertility was based on 10 sample panicles per plot while seed size was based on the weight of 1000 grains. The number of days to maturity was reckoned from date of planting to the date when 80% of the grains have turned straw brown while grain yield ha^{-1} was estimated on a 1-m^2 crop cut at the middle portion of each plot adjusting the weight to 14% moisture content.

Data Analysis

Agronomic data of individual year were analyzed using Analysis of Variance (F-test) in RCBD. Where F-test showed significant result, each TUR accession was compared with the check variety using Least Significant Difference (LSD) test. Data on grain yield was analyzed across years. As part of the results and discussion, data on plant height, seed size, maturity, panicle length, spikelet fertility and tiller count were clustered into distinct descriptive groups based on Standard Evaluation System for Rice (IRRI 2014) as follows:

Rating Scale:

[1]Plant height

<90 cm	-	Semi-dwarf
90-125 cm	-	Intermediate
>125 cm	-	Tall

[2]Tiller count

20-25 tillers/ plant	-	Good
10-19 tillers/ plant	-	Medium
<9	-	Low
90-100 days	-	Early

[3]Maturity

101-120	-	Medium
>120 days	-	Late maturing

[4]Panicle length

21-30cm	-	Medium
31-40cm	-	Long

[5]Seed size

20-23g	-	Small
24-27g	-	Medium
>28g	-	Big

[6]Spikelet Fertility

>90%	-	Highly fertile
75-89%	-	Fertile
50-74%	-	Partly sterile
<50% to trace	-	Highly sterile

RESULTS AND DISCUSSION

Growth parameters

Plant Height

Significant differences (P<0.01) were observed on plant height in both years (Table 1). However, plants were generally taller in 2013 than in 2014. This height difference could be attributed to higher total rainfall in 2013 with majority of the rain events occurred during the most critical growth period.

In 2013 WS, plant height ranged from 87.22cm (check) to 150.53cm. All the accessions were significantly taller than the check variety except six accessions (54, 56, 66, 67, 76 and 89) with plant height values which did not differ from the former. In 2014, plant height ranged from 88.60cm to 142.60 with only 25 accessions taller than the check. Considering the mean height for the two-year period, the accessions can be grouped into tall (>125cm) and intermediate stature (90-125cm). A total of 15 accessions as well as the check variety belonged to the latter group. Such finding conforms to the findings of Ortuose 2014 that upland rice cultivars are taller than modern varieties reaching up to 150 cm in height.

Number of Tillers

Significant difference between the TUR and the check variety was also observed on the number of tillers in both cropping years (Table 1). In contrast to plant height, the number of tillers was generally higher in 2014 than in 2013. More and heavier rains occurred during the active vegetative phase of the crop in 2014 than in 2013 (Fig. 1). In 2013 WS, the number of tillers of 46 accessions did not differ from the check variety. The remaining three accessions produced more tillers than the check. In 2014 WS, 17 accessions produced less tillers than the check. However, based on IRRIs classification, all the accessions belongs to medium-tillering category (10-19 tillers $hill^{-1}$). The growth and development of tillers depend partially on environmental factors, especially on radiation, temperature, and nutritional conditions and partially on varietal characteristics (Hanada 1993, as cited by Mohammad Nuruzzaman, *et al.*, 2000). In a similar study conducted in the lower elevation upland of Payao and Lubbot, in the City Batac, Ilocos Norte, results showed that most of the TUR entries were low-tillering, a characteristic of upland varieties (Badar *et al.*, 2012).

Table 1. Growth performance of TUR accessions in comparison with the check variety

TUR Acc	PLANT HEIGHT[1] (cm)		NO. OF TILLERS[2]		MATURITY (DAYS)[3]	
	2013 WS	2014 WS	2013 WS	2014 WS	2013 WS	2014 WS
51	150.53 H	138.20 H	10 N	13 L	116.00 N	113.67 N
52	135.00 H	110.93 N	10 N	16 N	115.00 N	114.00 N
53	142.13 H	121.53 H	11 N	12 L	118.00 N	117.00 N
54	94.66 N	97.26 N	21 H	17 N	126.00 H	126.33 H
55	145.20 H	125.80 H	12 N	13 L	113.33 N	113.00 N
56	115.53 N	115.26 N	6 N	14 L	113.33 N	113.00 N
57	135.73 H	111.81 N	10 N	13 L	113.67 N	114.00 N
58	134.93 H	118.26 N	96 N	15 N	113.33 N	113.67 N
59	130.46 H	118.33 N	11 N	14 L	122.00 H	122.33 H
60	135.93 H	122.20 H	10 N	18 N	118.67 N	119.67 N
61	143.86 H	115.93 N	12 N	12 L	117.00 N	118.67 N
62	144.26 H	140.40 H	10 N	18 N	114.67 N	115.00 N
63	139.53 H	124.60 H	10 N	15 N	122.67 H	123.67 H
64	130.26 H	135.00 H	10 N	17 N	123.33 H	123.00 H
65	146.53 H	128.10 H	13 N	15 N	119.67 N	122.00 H

Table 1. Continued

TUR Acc	PLANT HEIGHT[1] (cm) 2013 WS	2014 WS	NO. OF TILLERS[2] 2013WS	2014 WS	MATURITY (DAYS)[3] 2013 WS	2014 WS
66	116.53 N	106.33 N	10 N	18 N	117.33 N	117.33 N
67	119.53 N	115.70 N	10 N	14 L	114.33 N	114.67 N
68	139.20 H	136.40 H	10 N	17 N	119.00 N	117.00 N
69	140.20 H	119.13 N	14 H	14 L	117.33 N	121.67 H
70	128.26 H	115.46 N	8 N	17 N	122.00 H	124.00 H
71	140.53 H	110.86 N	10 N	11 L	114.00 N	113.67 N
72	151.33 H	124.46 H	14 H	16 N	114.67 N	113.67 N
73	136.60 H	113.80 N	12 N	18 N	114.00 N	114.33 N
74	130.06 H	122.40 H	9 N	15 N	122.33 H	124.00 H
75	138.00 H	128.60 H	12 N	21 N	122.67 H	122.67 H
76	114.66 N	105.60 N	12 N	17 N	121.67 H	122.00 H
77	143.66 H	142.60 H	9 N	19 N	120.00 N	120.00 N
78	131.06 H	123.06 H	7 N	16 N	115.67 N	117.67 N
79	144.40 H	132.73 H	10 N	14 L	122.33 H	123.67 H
80	141.13 H	132.00 H	9 N	14 L	115.67 N	117.00 N
81	136.80 H	120.93 H	8 N	16 N	115.00 N	115.67 N
82	138.53 H	130.80 H	10 N	15 N	122.67 H	123.00 H
83	138.00 H	125.66 H	9 N	16 N	120.00 N	120.33 N
84	131.33 H	122.73 H	10 N	18 N	119.33 N	120.67 N
85	127.46 H	118.06 N	9 N	12 L	113.67 N	114.00 N
86	147.13 H	125.80 H	10 N	15 N	116.67 N	118.33 N
87	117.86 H	108.60 N	9 N	19 N	115.67 N	118.67 N
88	131.00 H	116.33 N	11N	12 L	113.67 N	114.33 N
89	102.70 N	88.60 L	12 N	20 N	121.67 H	123.67 H
90	138.20 H	117.13 N	10 N	16 N	117.67 N	118.00 N
91	123.40 H	116.33 N	9 N	13 L	114.67 N	116.67 N
92	126.26 H	117.00 N	11N	16 N	116.00 N	119.33 N
93	129.93 H	114.46 N	7 N	15 N	114.33 N	117.00 N
94	137.73 H	133.33 H	9 N	16 N	116.67 N	119.00 N
95	143.40 H	129.06 H	9 N	15 N	118.00 N	120.67 N
96	138.80 H	117.73 N	11 N	16 N	119.33 N	121.67 N
97	147.00 H	130.86 H	9 N	14 L	124.00 H	125.00 H
98	149.00 H	102.53 N	11 N	13 L	113.67 N	113.67 N
99	140.13 H	119.40 H	10 N	16 N	117.67 N	118.67 N
Check (NSIC Rc 146)	87.20	102.06	9	20	117.00	119.00
Sig	**	**	**	*	**	**
CV(%)	7.58	8.73	25.98	20.51	2.30	2.41

** - significant at 1% level
* - significant at 5% level
In a column, means marked with H, N and L are significantly higher, not different, and significantly lower, respectively, than the check variety at $LSD_{0.05}$.

Maturity

The number of days to maturity varied significantly in both years with no apparent significant difference across year (113 to 126 days in 2013; and 113 to 125 in 2014). Most accessions were medium-maturing in both cropping years based on the classification scheme of *Oikeh et al.* (UD). In 2013, 12 accessions matured longer than the check while 14 accessions in 2014. TUR 54 which matured in 126 days was the latest to mature in both cropping years. This result was similar with the findings of Ortuose (2014) that maturity of the upland rice accessions in their study ranged from 122 to 126 days. None of the accessions was early maturing.

Yield and yield components

Panicle Length

Panicle length differed significantly in 2013 WS but not in 2014 WS (Table 2). In 2013, except TUR 63 with panicles classified as long, all the accessions as well as the check variety produced medium panicles as described in the Standard Evaluation System for Rice. There were only 5 accessions which are not significant to the check. In 2014, panicle length were not significant however, there were slightly more long-panicled than medium-panicled accessions. Panicle length ranged from 21.18cm to 35.51cm. This result could be partly attributed to the good rainfall pattern observed from vegetative to early reproductive stages of the crop during the 2014 WS. The significant variability in panicle length could be attributed to the genetic make-up of the accessions. The result obtained in 2013 was similar to the findings of Badar, *et al.* (2012) where the majority of the evaluated TURs in low-elevation upland produced medium panicles.

Seed Size

In 2013, two accessions, TUR 76 and TUR 89 were as small as the check entry while in 2014, 9 accessions were comparable to the check which is small (Table 2). This shows that majority of the TUR accessions had bigger seed size compared to the modern check, NSIC Rc 146. Differences in seed size might be attributed to the genetic make-up of the rice accessions. This conforms with the findings of Tahir *et al.* (2002) as cited by Khalil *et al.* (2009), who reported highly significant variation among different traits and observed that these traits are under the control of genotypic difference among the genotypes. Bharali *et al.* (1994) as cited by Khalil *et al.* (2009) reported the correlation and influence of 1000-grain weight by flag leaf area. Other factors like; adoptability, temperature, soil fertility, transplantation season and time might also be responsible for thousand grain weight. On the other hand, grain weight is determined by the supply of assimilates during the ripening period, and the capacity of the developing grain to accumulate the trans-located assimilates (Ntanos and Koutroubas, 2002). In addition, grain weight is a variable proportion of spikelet's sterility/ fertility regulated by moisture.

Therefore, one of the reasons behind grain yield loss with moisture stress may be the decrease in the number of filled grain per panicle (Atera, *et al.*, 2011).

Spikelet Fertility

Significant differences were observed in spikelet fertility of the different accessions evaluated (Table 2). TUR 84 was highly fertile in 2013, having 90.25%, followed by TUR 86, TUR 98, and TUR 72, which have 89.24%, 87.60% and 87.25% fertility, respectively. Meanwhile, in 2014, TUR 70 was highly fertile, having 91.28%, which was comparable to TUR 92, TUR 77, and TUR 78. Forty three and 44 accessions were as fertile as the check while six and 5 accessions had significantly lower spikelets fertility percentage than the check in 2013 and 2014 respectively.

Table 2. Yield components of the TUR accessions evaluated in the rainfed lowland of Batac, Ilocos Norte, 2013 and 2014 WS

TUR Acc	PANICLE LENGTH[4] (cm)		SEED SIZE[5] (g/1000 seeds)		SPIKELET FERTILITY[6] (%)	
	2013	2014	2013	2014	2013	2014
51	27.37 H	35.51	28.73 H	29.80 H	75.39 N	73.25 L
52	26.03 H	31.48	27.53 H	24.63 H	74.24 N	80.78 N
53	26.69 H	30.19	32.33 H	29.90 H	83.76 N	86.88 N
54	21.96 N	27.37	26.93 H	24.13 H	77.53 N	76.26 N
55	25.18 H	29.77	24.70 H	23.33 H	83.81 N	77.83 N
56	26.39 H	30.37	25.96 H	24,66 H	84.35 N	87.14 N
57	26.15 H	31.30	34.23 H	31.56 H	75.79 N	73.59 L
58	26.10 H	30.30	26.96 H	27.76 H	82.21 N	66.15 L
59	27.04 H	31.14	29.90 H	26.73 H	72.23 L	88.33 N
60	29.32 H	32.47	28.30 H	26.53 H	79.00 N	77.75 N
61	30.47 H	32.32	34.06 H	33.93 H	83.58 N	84.08 N
62	29.05 H	33.82	31.13 H	30.03 H	76.70 N	88.79 N
63	30.62 H	34.51	29.20 H	25.73 H	81.92 N	86.38 N
64	28.85 H	32.44	29.36 H	27.53 H	77.43 N	76.27 N
65	29.17 H	31.77	31.03 H	28.13 H	82.55 N	81.07 N
66	23.73 N	27.05	27.60 H	21.63 N	74.61 N	61.99 L
67	26.46 H	27.81	28.00 H	26.06 H	80.86 N	86.42 N
68	28.29 H	30.92	34.40 H	30.10 H	76.68 N	83.07 N
69	26.58 H	28.74	30.16 H	28.70 N	69.83 L	78.51 N
70	25.19 H	31,68	28.93 H	25.06 H	75.01 N	91.28 N
71	28.33 H	28.58	33.80 H	31.13 H	84.78 N	86.96 N
72	28.55 H	29.85	31.30 H	28.96 H	87.25 N	84.64 N
73	27.29 H	32.24	28.90 H	26.50 H	71.21 L	78.61 N
74	29.33 H	31.21	27.13 H	25.16 H	79.62 N	79.89 N
75	29.04 H	31.78	28.20 H	26.73 H	71.98 L	80.72 N
76	23.56 N	28.07	21.86 N	17.70 N	87.04 N	79.60 N
77	29.12 H	30.09	26.66 H	22.36 N	82.83 N	89.19 N
78	26.38 H	29.76	26.36 H	24.56 H	86.29 N	89.08 N
79	28.83 H	30.80	30.56 H	30.36 H	83.20 N	86.34 N
80	29.10 H	31.94	30.66 H	27.63 H	86.21 N	84.34 N
81	27.22 H	29.16	27.33 H	26.63 H	76.63 N	88.82 N
82	26.09 H	31.14	25.36 H	22.16 N	81.40 N	75.55 N
83	26.93 H	31.36	29.36 H	28.76 H	75.64 N	88.83 N
84	28.41 H	31.02	31.96 H	28.40 H	90.25 N	85.99 N
85	26.64 H	28.84	27.46 H	24.16 H	82.14 N	84.61 N
86	28.46 H	30.89	28.43 H	21.96 N	89.24 N	78.92 N
87	23.54 N	28.53	24.10 H	22.83 N	78.18 N	82.60 N
88	25.56 H	29.65	32.00 H	28.86 H	68.46 L	77.32 N
89	22.28 N	27.66	22.93 N	20.86 N	70.91 L	56.67 L
90	24.41 H	30.04	27.33 H	23.80 H	83.06 N	84.50 N
91	27.94 H	30.03	29.73 H	27.50 H	87.10 N	86.76 N
92	25.57 H	32.79	31.50 H	27.46 H	86.92 N	89.72 N
93	27.03 H	31.45	26.16 H	29.30 H	82.20 N	88.13 N
94	26.99 H	21.18	32.50 H	22.36 N	79.70 N	81.92 N
95	28.89 H	34.08	27.80 H	26.50 H	79.84 N	83.57 N

Table 2. Continued

TUR Acc	PANICLE LENGTH[4] (cm)		SEED SIZE[5] (g/1000 seeds)		SPIKELET FERTILITY[6] (%)	
	2013	2014	2013	2014	2013	2014
96	27.26 H	32.76	26.53 H	23.83 H	80.24 N	78.72 N
97	28.33 H	32.55	32.66 H	31.13 H	81.65 N	83.21 N
98	27.58 H	30.13	30.66 H	27.63 H	87.60 N	83.13 N
99	26.96 H	32.14	23.66 H	20.93 N	87.57 N	81.03 N
Check (NSIC Rc 146)	21.15	30.28	20.63	18.16	78.94	83.59
Sig	**	ns	*	**	**	**
CV(%)	7.10	10.76	3.48	4.88	8.94	28.37

** - significant at 1% level
* - significant at 5% level
ns - not significant
In a column, means marked with H, N and L are significantly higher, not different, and significantly lower, respectively, than the check variety at $LSD_{0.05}$.

Table 3. Main yield (t ha^{-1}) of the TUR accessions evaluated in the rainfed lowland of Batac, Ilocos Norte, 2013 and 2014 WS

TREATMENT	YIELD (kg ha^{-1})	YIELD ADVANTAGE OVER THE CHECK (%)
Year (Y)	ns	
Year 1 (2013)	2511.11	
Year 2 (2014)	2543.70	
Accessions (V)	*	
51	1605.03 L	-25.46
52	2209.23 N	8.59
53	3287.23 H	38.78
54	3105.58 H	34.88
55	2668.83 H	24.34
56	2015.27 N	0
57	1763.36 L	-14.77
58	2560.00 H	21.09
59	1659.99 L	-21.69
60	2706.06 H	25.46
61	2729.32 H	26.00
62	1849.28 L	-9.18
63	2810.81 H	28.11
64	2869.85 H	29.61
65	2289.52 N	11.77
66	2194.46 N	7.76
67	3069.41 H	34.20
68	1946.87 N	-3.58
69	1865.87 L	-8.02
70	2213.54 N	8.59
71	2934.88 H	31.05

Table 3. Continued

TREATMENT	YIELD (kg ha^{-1})	YIELD ADVANTAGE OVER THE CHECK (%)
72	3562.10 H	43.25
73	1867.44 L	-8.02
74	4167.84 H	51.55
75	2223.17 N	9.00
76	1973.35 N	-2.53
77	3301.46 H	38.78
78	3013.12 H	32.89
79	2821.69 H	28.36
80	2236.54 N	9.82
81	3004.25 H	32.67
82	2842.44 H	28.87
83	3001.32 H	32.67
84	3112.32 H	35.04
85	2641.26 H	23.48
86	1788.59 L	-12.84
87	1387.28 L	-45.32
88	2370.39 N	14.76
89	1618.58 L	-24.69
90	3118.30 H	35.25
91	2588.63 H	22.00
92	2332.87 N	13.30
93	3271.55 H	38.22
94	2685.98 H	24.90
95	2725.87 H	26.00
96	2267.78 N	11.01
97	2975.30 H	32.22
98	2942.48 H	31.29
99	2127.93 N	5.16
Check (NSIC Rc 146)	2021.19	-
Y x V	ns	
CV(%)	46.60	

** - significant at 1% level
* - significant at 5% level
ns - not significant
In a column, means marked with H, N and L are significantly higher, not different, and significantly lower, respectively, than the check variety at $LSD_{0.05}$.

Grain Yield

Combined analysis across years showed significant differences on the varieties/accessions but not on year, and variety x year (Table 3). Twenty seven accessions produced significantly higher grain yield than the check and 9 accessions produced significantly lower yield than the check. A yield advantage of 5.07% to 51.53% over the check was likewise obtained.

Four entries, TUR 53, 74, 72 and 77, are within the yield range of 3.3t ha^{-1} to 4.17t ha^{-1} obtained from the six promising accessions evaluated in low elevation upland (Badar *et al.*, 2012). The high yield obtained from them could be attributed to their high spikelet fertility in combination with bigger seed size (in TUR 53), many productive tillers (in TUR 72), long panicles (in both TUR 74 and 77) and also on the varietal yielding capabilities of the accessions as described by Ortuose 2014. The same variability were reported by Zahid *et al.* (2005), who studied twelve genotypes of coarse rice to check their yield performance in Kallar tract and reported highly significant variation for different traits. This variation in the grain yield might be due to the environment (Mahpattra, 1993 as cited by Khalil, 2009) or the correlation of grain yield $plant^{-1}$ with various yield contributing characteristics like: fertility of soil, flag leaf area, grains $panicle^{-1}$, number of grains $panicle^{-1}$ and grain weight and correlation with these traits.

The average yield obtained from these evaluation of TUR is also higher in the upland (2.14t ha^{-1} to 4.67t ha^{-1}), (Badar *et al.*, 2012) than in the rainfed lowland (1.39t ha^{-1} to 4.17t ha^{-1}). A similar result was reported by Alibuyog *et al.* (2015), who obtained higher yield from traditional varieties in the upland (1.49kg ha^{-1} to 6.99kg ha^{-1}) than in the rainfed lowland (0.96t ha^{-1} to 5.30t ha^{-1}). This implies that these traditional varieties are more adaptable in upland agro-ecosystems.

CONCLUSIONS

The TUR accessions showed variability in their agronomic performance. Characteristics such as tiller count, panicle length and spikelets fertility were the directly determinants of the grain yield of the evaluated accessions. Among the accessions, TUR 53, 72, 74, and 77 were the most promising based on grain yield with yield potential of 3.3. to 4.17t ha^{-1}. These have fertile spikelets, medium-sized panicles, medium tillering capacity, and medium to big seeds.

A confirmatory trial (farmer managed) using the identified high-yielding accessions in farmers' fields is recommended to validate the agronomic performance of the identified accessions. Purification, seed production and re-introduction of good/promising accessions to the upland rice farmers should be initiated next.

LITERATURE CITED

Alibuyog, A.Y., Solero, J.M., Rosales, R.J.G., and Bartolome, M.A.B. (2015). Abstracts of Paper Presentations. 28th National Rice R&D Conference. PhilRice, Central Experiment Station, Maligaya, City of Munoz, Nueva Ecija, September 9-10, 2015.

Atera, E.A, Onyango, J.C., Azuma, T., Asanuma, S. and Itoh, K. (2010). Afr. J. Agric Res. pp 4-5.

Badar, A.J., Antonio, M.A., Bucao, D.S., Agustin, E.O. and Gorospe, M.B. (2012). Promising Traditional Upland Rices Adaptable to Low Elevation Upland Areas (Unpublished). 24th Regional Symposium, Teatro Ilocandia, Mariano Marcos State University, City of Batac, October 31, 2012.

George, T., Magbanua, R., Roder, W., Van Keer, K., Trebuil, G., and Reoma, V. (2001). Upland rice response to phosphorus fertilization in Asia. Agron, 93, 1362-1370.

Hossain, M.B., Islam, M.O., Hasanuzzaman M. (2008). Influence of different nitrogen levels on the performance of four aromatic rice varieties. International Journal of Agriculture and Biology. 2008;10(6):693–696.

Hussain, S., Ramzan, M., Aslam, M., Manzoor, Z. and Ehsan Safdar, M. (2005). Effect of Various Stand Establishment Method on Yield and Yield Components of Rice. Proceedings of the International Seminar on Rice Crop. October 2-3. Rice Research Institute, Kala Shah Kau, Pakistan. pp. 212-220.

Khalil, I., Abdul Bari, H.I., Khan, S. and Zada, I. (2009). Genetic Variation for Yield and Yield Components in Rice. ARPN Journal of Agricultural and Biological Science. Vol. 4, No. 6, November 2009. ISSN 1990-6145.

IRRI (2014). Standard Evaluation System for Rice. 5^{th} ed. June 2014. ISBN 978-971-22-0304-6.

Nuruzzaman, M., Yamamoto, Y., Youji, N., Yoshida, T. and Miyazaki, A. (2000). Varietal differences in tillering ability of fourteen Japonica and Indica rice varieties. Soil Science and Plant Nutrition. 46:2, 381 -391.

National Statistical Center. (2004). Statistical Yearbook 2003. National Statistical Center Venttiane, 144 pp.

Ntanos, D.A., and Koutroubas, S.D. (2002). Dry matter and N accumulation and translocation for Indica and Japonica rice under Mediterranean conditions. Field Crops Res. 74:93-101.

Science and Technology Journal ISSN: 2012 0060
Vol. VIII 2018 Issue

EFFECT OF AIR TEMPERATURE AND PURPLE BLOTCH (*Alternaria porri*) DAMAGE ON THE YIELD OF GARLIC (*Allium sativum* cv. 'Ilocos White') IN ILOCOS NORTE, PHILIPPINES

Evangeline S. Galacgac and Leticia A. Lutap*

ABSTRACT

Garlic is a good source of income, but there was a yearly variation in the yield due to changing weather and diseases. The research was implemented to determine the relationship between air temperature and the degree of purple blotch damage to the yield of garlic. Production data from the experiment conducted at the Mariano Marcos State University and yield data from farmers were considered in the analysis. Air temperature was gathered from the two weather stations in Ilocos Norte. The degree of purple blotch damage was monitored at different phenophases of the crop. The relationship between air temperature and the purple blotch damage and garlic yield was determined using regression analysis. Likewise, the yield was correlated with the air temperature and the degree of purple blotch damage to the plants.

Air temperature and purple blotch damage were negatively correlated and significantly affected the size and weight of the bulb, indicating that the lower the mean air temperature, i.e., <25°C, and the lower the purple blotch infection or damage during the bolting stage of the plants, the higher the yield or the bigger and heavier bulbs it produced.

Keywords: *garlic, purple blotch, weather related diseases of garlic, garlic phenophases*

INTRODUCTION

Garlic farming remains a profitable endeavor in the Philippines (Dar, 2017). The province of Ilocos Norte is the country's top producer of garlic, contributing 63.5% of the total production (BAS, 2017). Garlic production grew at an average annual rate of 6.0%, from 8.81 thousand m.t. in 2012 to 10.42 thousand m.t. in 2015. However, in 2016, garlic production dropped to 7.47 thousand m.t. or by 28.3% from its 2015 level. The decrease was associated with smaller bulbs harvested in Ilocos Norte due to rainshowers during bulb formation. Ilocos Region topped all the garlic-producing regions with 4.49 thousand m.t. and shared 60.1% of the 2016 total output (PSA, 2018).

Weather is one of the factors that play a significant impact on the production and yield of garlic. Air temperature during the bolting stage is critical in which temperature should be maintained at 20°C (Rahim and Fordham, 2001). However, the previous condition on air temperature in Ilocos Norte is so erratic, especially during the regular cool months that is, January and February, coinciding with the crop's bolting stage. The normal minimum air temperature for January is 18.5°C, but it was observed to be as high as 20°C and as low as 14°C for the last 10 years.

According to VR Mamaril (Garlic Production Guide, Africa), garlic is more productive during cool months when the days are shortest since bulb formation occurs at

**Corresponding Author Current Address: Research Directorate Mariano Marcos State University, City of Batac, Ilocos Norte 2906 Philippines; email: esgalacgac@yahoo.com*

this period. Bolting stage is one of the most sensitive phenological stage of garlic. It was observed that when exposed to a high temperature before bulb initiation and during the growth and development of bulb, bulb production is low. Some research results showed that when the minimum temperature is low (about 16°C to 19°C), bulb size is bigger, and weight is heavier than when the temperature is above 20°C (Rahim and Fordham, 2001). According to Mojtahedi *et al.* (2013), as cited by Cuinan Wu *et al.* (2015), low temperature is the main factor for garlic bolting that affects bulb growth and it is the pre-requisite for higher yield in garlic. During bulbing or bulb development, cool temperature of 10-15°C helps produce larger bulbs. Cool and dry periods favour the production of the best quality bulbs. Other research proved that the best monthly average temperature range for growing garlic is from 13 to 24°C (Production guidelines for garlic, Africa; Yogesh, *et al.,* 2017). This crop cannot tolerate too hot or too cold climate impacts the development of bulbs. Basically, it prefers moderate temperature conditions (https://www.indiaagronet.com/horticulture).

On the other hand, purple blotch (*Alternaria porri* L.) has been identified as an important yield-limiting disease in garlic (*Allium sativum* L.) (Miller, 1983; Bisht and Thomas, 1992). In Ilocos Norte, it was observed that purple blotch occurred every year and had a great impact on the yield of garlic. A foliar infection of up to 90% has been reported in susceptible cultivars of garlic (Bisht and Agarwal, 1993). A significant reduction in bulb yield ranges between 25 to 60% due to varying degrees of defoliation (Bisht *et al.,* 1993).

In the Philippines, early planting of garlic, which starts in October, minimizes the risk of insect pest infestation. However, the possible occurrence of tropical depressions and typhoons predisposes the crop to fungal infection because of waterlogging in low-lying areas. On the other hand, late planting, which starts in December, exposes insect pests and diseases since the vegetative growth coincides with the dry and warm months of February and March.

Previous researches had been conducted on phenology, post-harvest, and cultural management but not so concentrated on the effect of air temperature and pest incidence on the yield of garlic. Therefore, the study was conducted to determine the relationship between air temperature and the degree of purple blotch damage to garlic yield.

METHODOLOGY

Garlic bulbs were planted in October 2012 to 2015, November 2008 to 2011, and December 2012 to 2015 cropping seasons in an area of 185 m^2 located near the MMSU-PAGASA-PCARRD Agrometeorological station. The production technology for garlic was followed with a fertilizer rate of 90-60-60kg NPK^{-1} ha. All P and K and two-thirds of N requirement was applied as basal with two split applications. The remaining N was side dressed at 35 days after planting (DAP). Organic fertilizer was also applied as basal before planting at a rate of 40 bags ha^{-1}. The plants were irrigated every other week. No pesticide was applied except those planted in November 2012 to 2015 cropping seasons to allow the determination of the first occurrence and degree of purple blotch damage to the plants. Garlic bulbs planted in November 2012 to 2015 were sprayed with pesticides before and during the bolting stage of the plants when the relative humidity was >88%. Purple blotch was evident at early bolting stage or the development of 8^{th} leaf when there was an occurrence of rainfall or when relative humidity is >88% (Galacgac *et al.,* 2011). The degree of purple blotch infection was estimated using the rating scales and descriptions for purple blotch damage (Cocson, 2014) as follows:

Table 1. Rating scale and description for purple blotch damage

RATING SCALE	% OF PLANT DAMAGE	DESCRIPTION
0	0	Clear
1	5-10	Slight
3	11-25	Moderate
5	26-50	High
7	51-75	Very high
9	76-100	Severe

The size of the bulbs was based on measurement of polar and equatorial diameters and individual weight of 10 sample bulbs. The yield was estimated using the recorded weight of the bulb samples. The size of bulbs was further classified using the Garlic Grading scale and description from the Descriptors for *Allium* (*Alliums spp.*) (IPGRI, 2001) as shown in the table below.

Table 2. Grading scale for garlic

CLASS	SIZE (cm)	DESCRIPTION
A	>4.0	Extra Large
B	3.6-4.0	Extra
C	3.1-3.5	Large
D	2.6-3.0	Medium
E	2.1-2.5	Small
F	<2.0	Reject

Data on air temperature was gathered in MMSU-PAGASA Agrometeorological Station (18° 3' N latitude, 120° 53' E longitude at an elevation of about 17.9m above mean sea level). The average air temperature from the occurrence of the 8th leaf to the 13th leaf (45-69 DAP) of the plants that coincided with the bolting stage was considered. Correlation and regression analyses were used to determine the influence or effect and relationship, respectively, between air temperature and degree of purple blotch damage to the yield of garlic. Likewise, correlation and regression analyses were done between the equatorial and polar diameters of the bulbs, with the bulb weight. The weight of the bulb was also correlated with the degree of purple blotch damage to plants. Moreover, regression analysis was also used to determine the relationship between air temperature and degree of purple blotch damage with the weight of the bulb of garlic. The data on the average garlic production of Ilocos Norte from 2010-2016 were documented. The said data was taken from the Ilocos Norte Provincial Agriculture Office. The mean air temperature in December and January, which coincided with the bolting stage of garlic were considered. The yield was correlated with the air temperature. Regression analysis was also used to determine the relationship between air temperature and the yield of garlic.

CONCEPTUAL FRAMEWORK

Bulb quality (size and weight) and ultimately the yield of garlic are highly affected by air temperature and purple blotch damage as shown in Figure 1. The degree of purple blotch damage to the crop is indirectly affected by air temperature .

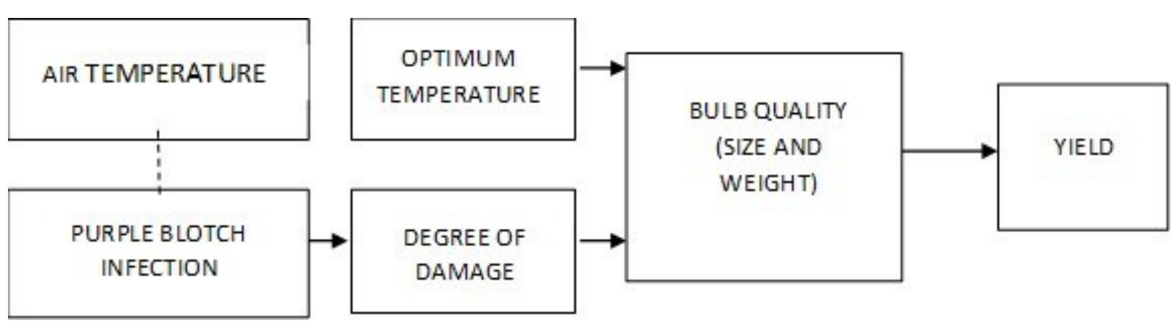

Figure 1. Conceptual framework of the study

RESULTS AND DISCUSSION

Air temperature at bolting stage of garlic

The average air temperature during October 2012, 2014, and 2015 cropping seasons was >25°C. It was only in the year 2013 that the average air temperature was <25°C. On the other hand, during the November 2008-2011 cropping seasons, it was observed that the average air temperature was <25°C. The average air temperature in December 2014 and 2015 cropping seasons was >25°C and in 2013 it was <25°C (Table 3). According to the Production Guidelines for Garlic from the DA-Forestry and Fisheries of South Africa, the best monthly average temperature range for growing garlic is from 13 to 24°C. During bulbing or bulb development, cool temperature of 10-15°C helps produce larger bulbs.

Purple blotch incidence at bolting stage of garlic

In October 2012-2015 cropping seasons, the degree of purple blotch damage was moderate to severe. There was a high infection of purple blotch in 2011 and moderate infection in 2009 during the November cropping seasons. In 2008 and 2010, there was only a slight infection of purple blotch. In December cropping seasons, moderate infection of purple blotch was observed in 2014. In 2015, a very high infection of purple blotch was noticed (Table 3). A foliar infection of up to 90% has been reported in susceptible cultivars of garlic (Bisht and Agarwal, 1993) with a significant reduction in bulb yield ranging between 25 to 60% due to varying degrees of defoliation (Bisht *et al.,* 1993).

Yield of Garlic

The yield of garlic at different planting months were summarized as follows:

October planting

The yield of garlic planted in October 2012-2015 cropping seasons in Batac, Ilocos Norte, which were not applied with pesticides, varies every year. The average bulb weight, polar diameter, and equatorial diameter in the 2013 planting season were the highest, and the size was considered large. It was noticed that even if there was a high infection of purple blotch in 2013, the mean air temperature is <25°C; however, the crop still produced heavy and large bulbs (Table 3). On the other hand, the lowest yield was observed in the 2015 cropping season. It can be noted that the plants were severely infected by purple blotch, and at the same time, the temperature was >25°C. The size produced in 2015 planting season was considered small, and in 2012 and 2014, they were under the medium category.

November planting

a. No pesticide application

The yield of garlic during the November 2008-2011 cropping seasons in Batac, Ilocos Norte, also varies every year. The average bulb weight, polar diameter, and equatorial diameter in the 2008 planting season were the highest, and the lowest was in the 2011 planting season. However, the sizes of bulbs were considered large to extra (3.1-4.0cm). Based on the result, the bulbs were still big and heavy if the average air temperature is <25°C, even if there was a high infection of purple blotch in 2011 (Table 3).

b. With pesticide application

Yield of garlic during the November 2012-2015 planting seasons wherein the plants were sprayed with pesticides before and during the bolting stage of the crop is shown in Table 4. The highest yield was observed in 2013 and 2014 planting seasons, and the least was in 2015. The sizes produced in 2013 and 2015 were considered large to extra, while in 2013 planting season, it was considered generally large. In 2015, the sizes of the bulbs were under the medium category. The size and weight of the bulb were heavier and larger when the average air temperature was <25°C. The degree of purple blotch damage in 2013 and 2014 was slight. In 2012, purple blotch damage was moderate and high damage in 2015 planting season.

December planting

During the December 2013-2015 planting seasons, the highest yield was observed in 2013, followed by 2014, and the lowest was in 2015. The size of the bulb in 2013 and 2014 fall under the large category. The degree of purple blotch damage was slight and moderate, respectively. In the 2015 planting season, they were considered medium (Table 3).

Based on the results, highest yield was obtained during November plantings, followed by December and the least was during October plantings. Furthermore, the size of the bulb (equatorial and polar) affected the weight of the bulb of garlic, indicating that the bigger the bulb, the heavier the weight. On the other hand, when

Table 3. Garlic yield, air temperature, and degree of purple blotch damage per trial during October, November, and December planting seasons without pesticide application

PLANTING MONTHS	YEAR/ TRIAL	YIELD			AVERAGE AIR TEMPERATURE (°C)	PURPLE BLOTCH DAMAGE RATING
		BULB WEIGHT (g)	EQUATORIAL DIAMETER (cm)	POLAR DIAMETER (cm)		
October	2012	10.2	2.8	2.5	25.5	7
	2013	17.6	3.3	3.2	24.3	5
	2014	11.3	3.0	2.8	26.7	3
	2015	7.3	2.4	2.2	26.6	9
November	2008	26.2	4.3	3.4	24.7	1
	2009	20.8	3.6	3.2	23.8	3
	2010	25.0	3.5	4.0	24.5	1
	2011	16.8	3.1	3.4	25.0	7
December	2013	16.3	3.3	3.2	22.0	1
	2014	12.8	3.2	3.2	25.3	3
	2015	10.3	3.0	2.9	25.3	7

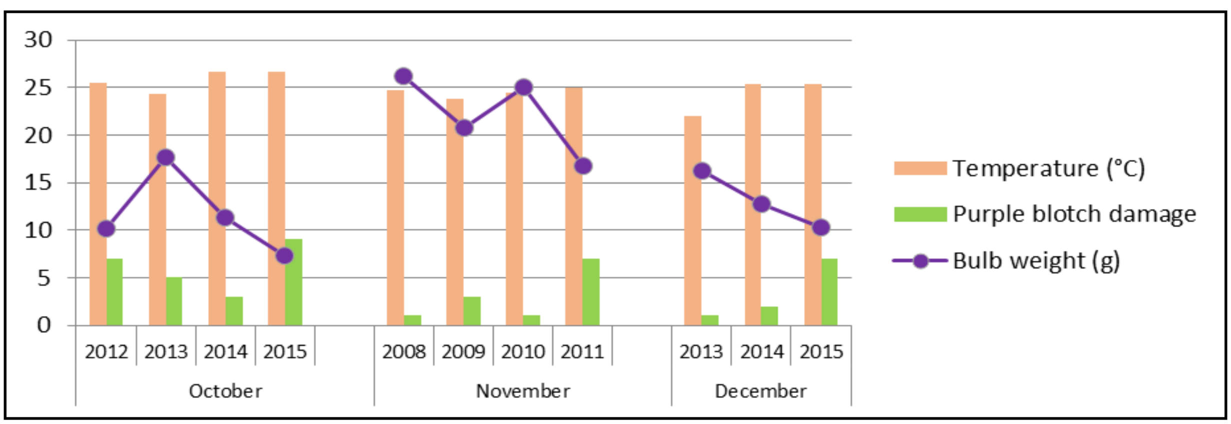

Figure 2. Bulb weight, air temperature, and degree of purple blotch damage during October, November, and December planting seasons

Table 4. Garlic yield, air temperature, and degree of purple blotch damage per trial during November cropping season with pesticide application

YEAR/ TRIAL	BULB WEIGHT (g)	YIELD EQUATORIAL DIAMETER (cm)	POLAR DIAMETER (cm)	AVERAGE AIR TEMPERATURE (°C)	PURPLE BLOTCH DAMAGE RATING
2012	17.0	3.3	3.3	24.0	3
2013	24.0	4.0	3.9	21.7	1
2014	23.5	4.0	3.8	22.0	1
2015	11.4	2.9	3.0	25.4	5

the average air temperature was <25°C, the weight of the bulb was numerically higher. Likewise, the degree of purple blotch damage affects the yield of garlic. The higher the degree of purple blotch damage, the smaller and lighter bulbs it produced (Figure 2).

Relationship between yield and temperature and purple blotch damage

No pesticide application

Air temperature was negatively correlated with the bulb weight, but there was no significant effect. The degree of purple blotch damage has a strong negative correlation and showed a significant effect on bulb weight. The result summarizes that it was only the degree of purple blotch damage that significantly affected the yield of garlic. This result indicates that the higher the purple blotch infection, the lower the yield of the plants. The high infection may be due to the non-application of pesticides before and during the bolting stage of the plants (Table 5). Although, temperature has a great impact on the size of garlic if the plants are severely infected with diseases, this may affect the decrease or reduction in yield.

With pesticide application

Correlation and regression analyses show that the equatorial and polar diameter of the bulb has a strong positive correlation and significantly affected the weight of the bulb. Likewise, air temperature and the degree of purple blotch damage had a strong negative correlation and significantly affected the weight of the bulb. Air temperature and the degree of purple blotch damage affected the weight of the bulb, indicating that the higher the air temperature and the higher the purple blotch infection or damage, the lower the yield of the plants (Table 6).

Relationship between yield and temperature on garlic production in Ilocos Norte

Garlic production in Ilocos Norte from 2010-2016 (2009-2015 cropping seasons), shows that the highest yield was observed in 2014 and 2015 with a production of 3.5 MT per hectare (Table 7). Meanwhile, in 2016, there was an abrupt change of production. It goes down to almost half of in year 2015. Based on actual observation on garlic production all throughout the different municipalities of Ilocos Norte, the general size of the bulbs in 2016 was from small to medium. The mean air temperature from 2010-2015 was <25°C. In 2016, the mean air temperature was >25.0°C. Based on correlation and regression analysis, the mean air temperature has a moderate negative correlation and significantly affected the yield of garlic. Dr. P. Syam Sundar Reddy stated that low temperature is the pre-requisite for higher yield in garlic. Cool and moist condition is required for proper vegetative growth. During bulbing and bulb development, the optimum temperature for

Table 5. Correlation between bulb weight to equatorial and polar diameter, air temperature, and purple blotch damage

	EQUATORIAL DIAMETER (cm)	POLAR DIAMETER (cm)	AVERAGE AIR TEMPERATURE (°C)	PURPLE BLOTCH DAMAGE
Correlation (coef.)	0.9065**	0.8544**	-0.5312^{ns}	-0.7250**
Regression (R^2)	0.8218**	0.7301**	0.2024^{ns}	0.5256**
SD	0.49	0.48	1.30	2.87

** - significant at 1% level
* - significant at 5% level
ns - not significant

Table 6. Correlation between bulb weight to equatorial and polar diameter, air temperature, and purple blotch damage to plants with pesticide application during November cropping season

	EQUATORIAL DIAMETER (cm)	POLAR DIAMETER (cm)	AVERAGE AIR TEMPERATURE (°C)	PURPLE BLOTCH DAMAGE RATING
Correlation (coef.)	-0.9955*	0.9932**	-0.9976**	-0.9983**
Regression (R^2)	0.9865**	0.9797**	0.9929**	0.9949**
SD	0.69	0.60	0.15	0.14

** - significant at 1% level
* - significant at 5% level
ns - not significant

Table 7. Average garlic production and air temperature in Ilocos Norte from 2010-2016 (2009-2015 planting seasons)

YEAR	YIELD (MT/hectare)	AVERAGE AIR TEMPERATURE (°C)
2010	2.89	24.1
2011	2.97	24.7
2012	2.95	24.4
2013	3.04	24.6
2014	3.48	22.7
2015	3.50	24.5
2016	1.88	25.7
Correlation Analysis (coef.)		-0.7586*
Regression Analysis (R^2)		0.5754*
SD		0.384

** - significant at 1% level
* - significant at 5% level
ns - not significant

garlic is 20-25°C. Cool and dry period favor the production of best quality bulbs.

CONCLUSIONS AND RECOMMENDATIONS

Garlic yield responded to lower temperatures. Bulb size is bigger, and weight is heavier when the average air temperature was <25°C during the bolting stage of the plants. Air temperature and purple blotch damage have a strong negative correlation and significantly affected the weight of the bulb, indicating that the higher the temperature (>25°C) and the higher the purple blotch infection or damage to the plants, the lower the yield.

Based on the result of the study, proper management, especially on the prevention or control of purple blotch infection, is employed before and during the bolting stage of the plants. Since the yield will always depend on the weather condition, particularly the air temperature, this research will provide insight to offer environmental tools like adjustable temperatures during the bolting stage or, if possible, to come up with a variety that responds positively to higher temperature.

Lee, 2014 on his study on the effects of rapid temperature change on growth response and yield of garlic in greenhouse with thermostat control system in Jeonnam province states that growth and yield of garlic were more affected by decreased temperature than increased temperature at bulb development stage. Temperature influence the yield of garlic as shown in the study of El-Zohiri, 2015 on the effect of pre-soaking seed cloves and foliar spray of silicon (Si), selenium (Se) concentrations and their combinations on germination, early seedlings growth, marketable and total green yield as well as chemical constituents of garlic planted under high temperature conditions of late summer. It was concluded that pre-soaking seed cloves and foliar spray of the plant leaves by Si and Se together protect garlic plants from the high temperature stress during germination and growth initiations which, reflected on germination percentage, germination speed, vegetative growth and bulb characters as well as total green, marketable yield and its quality.

REFERENCES

Arcalas, J.Y. (2017). DA's Piñol eyes to raise garlic production in the next three years. Business Mirror. Retrieved from https://businessmirror.com.ph/das-pinol-eyes-to-raise-garlic-production-in-next-three-years/June 1, 2021.

Bisht, I.S. and Agarwal, R.S. (1993). Susceptibility of purple blotch (*Alternaria porri*) in garlic. Ann. Appl. Biol. 122:31-38.

Chaput, J. (1999). Identification of diseases and disorders of onions. Factsheet. Queen's Printer for Ontario.

Cuinan Wu, M.W., Yinxin D., Zhihui C., and Huanwen M. (2015). Growth, bolting and yield of garlic (*Allium sativum* L.) in response to clove chilling treatment. Scientia Horticulturae.

Department of Agriculture, Forestry and Fisheries. Republic of South Africa. Production guidelines for garlic. (http://www.nda.agric.za/docs/Brochures/prodGuideGarlic.pdf).

El-Zohiri, S.S.M. and Farag, A.A. (2015). Reduce the harmful effects of high temperature on the green garlic production for export. https:www.researchgate.net/publication/283259284.

Hatfield, J.L. and Prueger, J.H. Temperature extremes: Effect on plant growth and development.

Hickey, M. (2012). Growing garlic in NSW. Second edition. http://www.dpi.nsw.gov.au/factsheets.

IPGRI, ECP/GR, AVRDC (2001). Descriptors for Allium (Allium spp.). International Plant Genetic Resources Institute, Rome, Italy; European Cooperative Programme for Crop Genetic Resources Networks (ECP/GR), Asian Vegetable Research and Development Center, Taiwan.

Lee, K.D. (2014). Effects of Rapid Temperature Change on Growth Response and Yield of Garlic in Greenhouse with Thermostat Control System in Jeonnam Province. Korean Journal of Soil Science and Fertilizer, 47(6). pp 571-578. https://doi.org/10.7745/kjssf.2014.47.6.571.

Mamaril, V.R. Department of Agriculture-Bureau of Plant Industry. Garlic Production Guide. http://bpi.da.gov.ph/bpi/images/Production_guide/pdf/Garlic.pdf.

Maude, R.B. (1990). Leaf diseases of onions. Brewster (eds.), Onion Allied In: H.D. Rabinowitch, and J.L., Brewster (eds.), Onion, Allied. Crops. 3:173-189. CRC Press Inc. Boca Raton, Florida.

Meredith, D.S. (1966). Spore dispersal in *Alternaria porri* on onion in Nebraska. Ann. Appl. Biol. 57:67.

Miller, M.E. (1983). Effect of various levels of leaf damage of onion bulb yield. Phytopathology 73:504.

Mullen, M.C., Marcia, P. and Lamey, H.A. (2001). Plant diseases development and management. www.ag.ndsu. Nodak.edu.

Philippine Statistics Authority (PSA). (2018). Crops Statistics of the Philippines 2012-2016. Philippine Statistics Authority. p 29.

Rahim, M.A. and Fordham, R. (2001). Environmental manipulation for controlling bulbing in garlic. International Society of Horticultural Science. (http:/www.actahort.org/books/555/555_27.htm).

Syam, S.R.P. Environmental influence on growth, development and yield of vegetable crops. http://www.authorstream.com/Presentation/syamhort-466287-temp-on-growth-and-development.

Youssef, N.S. (2013). Growth and bulbing of garlic as influenced by low temperature and storage period treatments. World Rural Observations.

 ISSN: 2012 0060

ENHANCING SHELF LIFE OF TOMATO (*Solanum lycopersicon* L.) USING RICE STRAW AS STORAGE MEDIUM

Maura Luisa S. Gabriel, Marissa I. Atis, Aleta E. Dumaoal and Zenaida H. Esteban*

ABSTRACT

Storing tomatoes is already a practice of farmers in the province of Ilocos Norte, Philippines. It has become an added source of income, aside from farming. However, using their own practice, farmers encountered high rotting percentage. This study was conducted to evaluate and improve existing farmers' methods, identify appropriate container to use, and determine the optimum length of storing tomatoes.

Biological wastes, like rice straw, has been found effective as storage medium to enhance the shelf life of tomatoes. The incorporation of rice straw with tomatoes inside the storage container resulted in lower percentage rotting and maintained the quality of fruits. The container could be a paper box or a plastic sack, which is placed in an elevated area with good ventilation.

The length of time storing tomato is critical in determining the profitability. The longer the fruits are stored, the more fruits are rotten. It is profitable to store tomatoes for two months but not beyond 67 days.

Keywords: *Tomato shelf life, post-harvest storage of tomato, storage media for tomato, post harvest handling practices for tomato*

INTRODUCTION

Tomato (*Solanum lycopersicon* L.) is one of the most important and most cultivated vegetables worldwide. With the many uses and nutritional value of tomato, it is an indispensable ingredient in a man's diet. It is very important for most of the people in the Ilocos region because it is one of the main ingredients of the most famous Iluko vegetable dish 'pinakbet' or vegetable stew.

Production of tomato in the Philippines covers an area of 17,700 ha producing about 199,000 MT with an average of 10.10 MT ha^{-1} (BAS, 2010). The province of Ilocos Norte is one of the major producers of tomato in the country. In 2009, it ranked third in terms of its contribution (11.7%) to the total volume of production (BAS, 2010).

Ilocos Norte farmers usually plant tomato during the months of December to January, and the peak of harvest is observed in March. There is usually a market glut during the month of March and the price of tomato ranges from ₱3.00 to ₱5.00kg^{-1} only. However, during the rainy season from May to October, the price escalates to as much as ₱60 to ₱80kg^{-1}. It is during this time that some farmers store their produce to wait for a better price. Storage of commodities can be profitable when the quality of the product can be maintained for a longer period.

**Corresponding Author Current Address: Research Directorate Mariano Marcos State University, City of Batac, Ilocos Norte 2906 Philippines; email: marissa_atis@yahoo.com*

Refrigerated storage is so far the best method, but this is very costly. Refrigeration can keep tomato for 7 to 14 days (https://homecookbasics.com/how-long-do-tomatoes-last/#fresh-tomatoes). This will vary slightly depending on the kind of tomato. Several studies have been done to improve the storage practices of the farmers which will decrease rotting, maintain the quality of fruits and eventually increase profit. Other practices used to prolong the postharvest life of tomatoes at ambient temperatures are hanging (Tome and Bautista, 2018; Gabriel *et al.*, 2001); modified atmosphere storage (Torres M, 2005); using ash (Garcia and Bautista, 2016; Garcia ES, 2014); rice hull (Felipe CM, 2004); coco coir dust (Mariottt *et al.*, 2015), and modified atmosphere storage with coco coir dust (Masilungan, *et al.*, 2009 in http://mb.com.ph/articles/225764/scientists-develop-a-practical-way-storing-fresh-tomato). This storage technique, using Modified Atmosphere Packaging (MAP), prolongs the storage life of fresh tomatoes under ordinary condition using locally available materials.

Masilungan said that this MAP technology can be easily adopted by vegetable farmers at the village level production especially during periods when the price of tomato is low due to abundant supply, giving them up to three more weeks to store their produce while waiting for higher selling price.

Rice straw is a biological waste after separating the grains from the plant. It is abundant and available in the locality. Rice straw (RS) is high in silica and cellulose (http://animalfeedscience.com/article/SO377-8401(06)00050-2/abstract). These components are desiccants which maintain the relative humidity inside the container, and thus preserves the fruits. Thus, this study aimed to: 1) identify appropriate media and container for storing tomato fruits, 2) determine the optimum length of storing tomatoes and 3) evaluate the profitability of storing tomatoes using rice straw as a storage medium.

METHODOLOGY

Three independent experiments were conducted to develop a technology for storing tomato: a) Comparison of sawdust and RS as storage media using paper box, b) Evaluation of different containers with and without RS, and c) Optimum length of storing tomato using paper box with RS as storage medium. About 10kg of tomato fruits were used per experimental unit using harvested green mature fruits (var. Ilocos Red). The plants from which the test fruits were harvested were not irrigated one to two weeks before harvesting. Harvesting was done early in the morning.

All the three experiments were laid out in Completely Randomized Design (CRD) in three replicates with the following treatments:

The saw dust used was collected from nearby saw mill while the rice straw was taken from newly harvested rice plants. Both the rice straw (RS) and sawdust were sun-dried prior to use. The following treatments were used:

a. Comparison of sawdust and RS as storage media using paper box

T1- Paper box (measuring with approximately 35cm x 60cm x 0.4cm)

T2- Paper box + sawdust (sawdust were taken from a furniture shop then fully dried to kill the harbored microorganisms). The tomato fruits were embedded in sawdust inside the paper box. A layer of tomato fruits was placed, then covered with 2cm thick sawdust followed by another layer of fruits alternately with sawdust until the 10kg fruits were accommodated in the container, then sealed with packaging tape.

T3- Paper box + RS (freshly threshed RS was sun-dried for three days prior to use. Tomato fruits were placed inside the paper box lined with 2cm RS. A layer of tomato fruits was placed followed by a layer of RS until all the 10kg fruits were accommodated in the container, then similarly sealed with packaging tape.

b. Evaluation of different containers with and without RS

The treatments were: T1 - Paper box alone, T2 - Paper box + RS, T3 - Bamboo basket alone, T4 - Bamboo basket + RS, T5 - Plastic sack alone, and T6 - Plastic sack + RS.

c. Optimum length of storing tomato using paper box + RS as storage medium and stored for the following number of days: **T1** - 15 days, **T2** - 30 days, **T3** - 45 days, **T4** - 60 days, **T5** - 67 days, **T6** - 75 days, **T7** - 82 days, and **T8** - 90 days.

After packing the fruits, the containers were sealed. For the first two experiments, all the experimental units were placed under ambient temperature which ranged from 26.0°C to 34.0°C and a daily reading of relative humidity ranging from 64.0% to 88.3%. After two months of storage, the containers were opened and the stored tomatoes were evaluated. For the optimum storage length experiment, the packed tomatoes were placed under ambient temperature which ranged from 29.1 to 32.5°C and relative humidity which ranged from 57 to 73%.

Treatment effects were evaluated based on percent weight loss, rotting, and shriveling. Fruit quality after storage for the second and third experiments was also rated based on the following visual quality rating (VQR): 9, 8 - excellent, field fresh; 7, 6 - defects minor; 5, 4 - fair, defects moderate; 3 - poor, defects serious, limit of salability; 2 - limit of edibility; and 1 - non-edible. The price of tomato in the public market was also regularly monitored from the month of May to August to serve as input in the costs and returns analysis.

RESULTS AND DISCUSSION

Comparison of saw dust and RS as storage media

The incorporation of RS as storage medium resulted in significantly lower percentage rotting and consequently, higher marketable fruits than paper box with and without sawdust (Table 1). The high percentage of rotting in sawdust could be due to high moisture content of this storage medium. In contrast, RS as a storage medium served as cushion which does not allow the fruits to touch each other. As the fruits respire, heat is generated and water is also a product. The high porosity of RS absorbs the moisture produced and also prevented the building up of heat. This condition is contributory to the slower deterioration, lower rotting percentage and better quality of fruits. Temperature, moisture, gases and the presence of microorganisms

Table 1. Rotten and marketable fruits of tomato fruits as affected by rice straw and sawdust as storage media after two months of storage

STORAGE METHOD	ROTTEN FRUITS (%)	MARKETABLE FRUITS (%)
	**	**
Paper box + sawdust	39.59a	21.63c
Paper box + RS	3.75c	69.96a
Paper box	31.88ab	42.51ab
CV (%)	43.70	22.70

** - significant at 1% level

In a column, means marked with the same letter are not significantly different using LSD test at 1% level.

are the factors that affect the shelf life of a perishable commodity (Bautista and Esguerra, 2007). A low temperature slows down the metabolic activity slowing down the deterioration process. On the other hand, the paper box where the tomato was stored could have modified the atmosphere in the immediate environment of tomatoes by lowering the amount of oxygen and increasing the amount of carbon dioxide. This condition slows down also the metabolism of the commodity (Artes and Bautista, 2007). Lower moisture also inhibits the multiplication of microorganisms.

Evaluation of different containers for storage with or without RS

The treatments showed significant effect on the percentage of rotten fruits, marketable fruits, and weight loss. However, the percentage of shriveled fruits was not significantly affected.

In general, percent rotten fruits were significantly higher if without RS regardless of the container used in the following order paper box > bamboo basket > plastic sack (Table 2). With RS, the percentage of rotten fruits was more than six times less in paper box, three times in plastic sack and twice in bamboo basket.

Significantly higher percent weight loss and lower percent marketable fruits were observed in storage containers without RS. After two months of storage, percent marketable fruits were reduced to 64.44% in plastic sack and to 50.03 and 55.57% in paper box and wooden basket, respectively. With RS, the percentage of marketable fruits was only reduced by less than 25% regardless of the type of storage container. The incorporation of RS in the storage container provided aeration which probably controlled the building up of temperature inside the container.

In terms of VQR (general appearance, fruit color and juiciness), fruits stored in paper box + RS had the best quality with VQR value of 8 (excellent, field fresh). Except for bamboo basket storage container with a VQR of 6 (defects minor), all other treatments garners a rating of 7 which is also described as with minor defects.

Table 2. Percent rotten, shriveled and marketable fruits, percent weight loss and the visual quality rating of tomato fruits stored for two months using different containers with the incorporation of rice straw

CONTAINER	ROTTEN FRUITS (%)	SHRIVELED FRUITS (%)	MARKETABLE FRUITS (%)	WEIGHT LOSS (%)	VISUAL QUALITY RATING
	*	ns	*	*	-
Paper box	38.24a	2.57	50.03c	49.97a	7
Paper box + RS	6.39c	1.04	74.34ab	25.66bc	8
Bamboo basket	34.71ab	2.77	55.57bc	44.43ab	6
Bamboo basket + RS	16.25bc	6.04	77.92a	22.08c	7
Plastic sack	14.78bc	7.78	64.44abc	35.56abc	7
Plastic sack + RS	5.10c	6.14	77.11a	22.89c	7
CV (%)	56.60	68.80	33.10	33.10	-

* - significant at 5% level
ns - not significant
In a column, means marked with the same letter are not significantly different using LSD test at 5% level

Visual Quality Rating:

9,8 - excellent, field fresh	3 - poor, defects serious, limit of salability
7,6 - defects minor	2 - limit of edibility
5,4 - fair, defects moderate	1 - non-edible

Optimum length of storage using paper box with RS as storage medium

Stored tomato up to 15 and 30 days still showed good quality, VQR of 9 (excellent, field fresh), no rotten and shriveled fruits yet, and with minimal percent weight loss (Table 3). At 45 days, although rotting, overall quality and weight loss did not differ from 15 and 30 days of storage, a significant increase in the percentage of shriveled fruits was observed and the VQR already went down to 7 (minor defects). At 60 days, percent weight loss was significantly higher than the preceding storage periods but percent shriveled fruits did not increase significantly and hence, VQR was still 7.

At 67 days, 25.73% of the fruits were rotten. This increased abruptly to about 75% at 75 days and then to 91.03% at 82 days. A week later, almost all the fruits were rotten. In terms of weight loss, this registered 31.01% at 60 days increasing significantly to 78.67% at 75 days and then to more than 94% two weeks later. VQR also went down to 5 (fair, defects moderate) at 67 days, then 3 (poor, defects serious, limit of salability) at 72 days and ultimately 1 (non-edible) at 82 days.

Cost and return analysis

The price of tomatoes during the peak season was PhP5 kg^{-1}, on the average. The farmers stored 1000kg of their harvest from 15-90 days following the recommended RS storage technology (Table 4). As expected, the percentage recovery at different periods was decreasing. Assuming that the average market price per kilogram of tomato was constant for the first three weeks the fruits were stored, the highest return above variable cost (RAVC) was attained at 15 days of storage. This period also had the highest percent recovery. As the market price increased, the tomatoes stored for 60 days and sold gave the highest RAVC. Despite the decreasing recovery rate, the fruits were still of better quality hence, sold at a higher price compared to the previous periods.

Table 3. Rotten fruits, marketable fruits, weight loss, fruit recovery and visual quality rating of tomato fruits stored in paper box with rice straw at different length of storage

STORAGE LENGTH (day)	ROTTEN FRUITS (%)	MARKETABLE FRUITS (%)		WEIGHT LOSS (%)	RECOVERY (%)	VISUAL QUALITY RATING
		Good Quality	Shriveled			
	**	**	**	**	-	-
15	0.00d	100.00a	0c	2.33d	97.67	9
30	0.00d	100.00a	0c	5.83d	94.17	8,9
45	1.67d	92.34a	5.99b	13.00d	87.00	7
60	6.80d	85.50a	7.71b	31.33c	68.67	7
67	25.73c	58.98b	15.29a	40.33c	59.67	5
75	74.34b	17.34cd	8.32b	78.67b	21.33	3
82	91.03a	0.00d	8.97b	94.17a	5.83	1
90	98.77a	0.00d	1.23c	98.90a	1.10	1
CV (%)	12.10	7.70	57.10	12.20	-	-

** - significant at 1% level
ns - not significant
In a column, means marked with the same letter are not significantly different using LSD test at 1% level

Visual Quality Rating:

9,8 - excellent, field fresh	3 - poor, defects serious, limit of salability
7,6 - defects minor	2 - limit of edibility
5,4 - fair, defects moderate	1 - non-edible

Table 4. Cost and return analysis of tomato (1 ton) stored in paper box with RS at different number of days

ITEM	LENGTH OF STORAGE (days)							
	15	30	45	60	67	75	82	90
Cost of 1.0 ton tomato fruits @PhP5 kg^{-1}	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Packaging material, paper box	300	300	300	300	300	300	300	300
Rice straw (cost of hauling)	200	200	200	200	200	200	200	200
Labor	400	400	400	400	400	400	400	400
Sub-total	5,900	5,900	5,900	5,900	5,900	5,900	5,900	5,900
% Recovery	97.7	94.2	86.8	80.3	59.7	21.3	5.8	1.1
Weight of tomato fruits left (kg)	977	942	868	803	597	213	58	11
Actual market price	12	12	12	15	20	25	25	25
Gross Income (PhP)	11,724	11,304	10,416	12,045	11,940	5,325	1,450	275
RAVC (PhP)	5,824	5,404	4,516	6,145	6,040	-575	-4,450	-5,625
Increase of price by 50%	18	18	18	22.5	30	37.5	37.5	37.5
RAVC (PhP)	11,686	16,956	9,724	12,167	12,010	2,087	-3,725	-5488
Decrease of price by 50%	6	6	6	7.5	10	12.5	12.5	12.5
RAVC (PhP)	-38	-248	-692	122	70	-3238	-5175	-5762

Note: Average market price from 15-45 days is PhP12 kg^{-1} with the assumption that harvest is still at its peak.

Storing the product up to 60 days allowed the farmer to wait for a higher price and earned more income. In fact, a positive RAVC was still attained up to 67 days. This scenario was observed assuming a 50% increase in the price per kilogram due to the decreasing supply of tomatoes in the market over time.

Storing the product up to 60 days allowed the farmer to wait for a higher price and earned more income. In fact, a positive RAVC was still attained up to 67 days. This scenario was observed assuming a 50% increase in the price per kilogram due to the decreasing supply of tomatoes in the market over time.

CONCLUSIONS

Rice straw was the best medium identified in storing tomato using a paper box with a capacity of 10 kg. With better aeration, cushion, and absorption of moisture, rotting of the tomatoes was limited.

Sack can also be used as long as it is hanged or laid horizontally with good ventilation.

Tomatoes stored in a paper box with RS until 67 days was profitable. Longer storage resulted to negative returns.

Overall, tomatoes stored using the technology kept better quality of the fruits, sold timely at a higher price and gave higher returns for the farmers.

LITERATURE CITED

Bureau of Agricultural Statistics. (2010).

Felipe, C.M. (2004). Effects of storage methods on the shelflife of tomato fruits (var. Ilocos Red).

Gabriel, M.L.S., Pambid, Z.R. and Tagala, T.U. (2001). Prolonging the storage life of fresh market tomatoes. Paper presented during the 13th Regional Symposium of R&D Highlights. July 26-27, 2001 DMMMSU, Bacnotan, La Union.

Garcia, T.B. and Bautista, O.K. cited by IK Arah. (2016) Ah storage of tomatoes. Proc. of the 1st Seminar Workshop of the Society for the Advancement of the Vegetable Industry.

Garcia, E.S. cited by Y. Li. (2014). Storage of ripe tomatoes in rice hull ash moistened with different amounts of water. Unpublished undergraduate Thesis. College of Agriculture and Forestry. Mariano Marcos State University, Batac, Ilocos Norte 79 pp.

http://animalfeedscience.com/article/SO377-8401(06)00050-2/abstract.

https://homecookbasics.com/how-long-do-tomatoes-last/#fresh-tomatoes.

http://mb.com.ph/articles/225764/scientists-develop-a-practical-way-storing-fresh-tomato.

Marriott J., Been, B.O. and Perkins, C. cited by MC Menkiti. (2015). Storage of fresh cassava roots in moist coir dust. Sci. Hort. 10:177-181.

Masilungan, *et al.* (2009). in http://mb.com.ph/articles/225764/scientists-develop-a-practical-way-storing-fresh-tomato).

Tome E.P. and Bautista, O.K. cited by A Haile. (2018). Extension of storage life of tomatoes by hanging fruits with stem stub. Phil. J. Crop Sci. 22(1):30-38.

Torres, M. cited by Musser, G. and Carleton, M. (2005). Storage of tomato fruits under modified atmosphere conditions. DA-Bureau of Agricultural Research (BAR) and DOST-Philippine Council RDE Management on Dragon Fruit and Its Implication. pp. 894.

ISSN: 2012 0060

MULCHING AS A CONTROL STRATEGY FOR THE MAJOR PESTS OF TOMATO (*Solanum lycopersicum* L.) DURING THE WET SEASON

Marylis A. Nalundasan and Noralyn B. Legaspi*

ABSTRACT

Field experiments, to evaluate the effects of different mulching materials on the control of major pests and yield performance of tomato, were conducted at the MMSU, Experimental Farm, City of Batac during the wet season (WS) from 2012 to 2015. The following mulching materials were used as experimental treatments: plastic mulch (PM), rice straw (RS), dried grasses (DG), rice hull (RH), carbonized rice hull (CRH) and sawdust (SD). Unmulched treatment was included as the negative control.

Mulching materials such as RS and DG were effective as PM in controlling weeds. The common insect pests observed during the study period were fruitworm, leaf curling and leaf blight. The use of these mulching materials minimizes pest infestation and weed growth.

The marketable yield of tomato mulched with PM, DG and RS per hectare significantly obtained the highest during the four wet season trials. The lowest yield was significantly observed from the UM, SD, CRH and RH. In addition, the net return was highest with the use of PM at ₱390,350 with an average yield of 27.18 tha^{-1}, followed by using DG and RS. Hence, these two mulching materials such as RS and DG could be a good substitute for PM, which is costly. These are locally available and using these materials could provide a farmer a very good return.

Keywords: *Wet season tomato production, tomato pests, Integrated pest management, mulching materials*

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) belongs to the family *Solanaceae* and plays an important role in human diet. It is a valuable source of vitamins A and C, as well as several minerals including calcium, iron, manganese, and particularly potassium (Kaur and Kapoor, 2008). It also contains lycopene, which is a carotenoid (a pigment involved in photosynthesis) that gives red coloring to tomatoes (Kelley and Boyhan, 2010), as cited by Tegen *et al.*, 2016).

Tomato production during the wet season (WS) is very profitable. The price of tomato is very high and marketing is not a problem. However, there is high pest infestation during this period which adversely affect fruit yield although even in tomato varieties recommended for WS planting. Mulching positively influences crop growth and yield by balancing soil humidity, temperature and structure (Janina von Diest and Pia Addison, 2016).

In the Philippines, particularly in the Ilocos province, one of the present cultural practices of the farmers for the control of pest is the use of chemical pesticides which lead to pest outbreak or resurgence, and is aggravating insect pest and disease

**Corresponding Author Current Address: Research Directorate*
Mariano Marcos State University, City of Batac, Ilocos Norte 2906 Philippines
email: ma_nalundasan@yahoo.com.ph

problems in producing vegetables (LA Lutap and MI Atis, 2013). Insect pests and diseases of tomato are managed by using chemical, biological, and remedial measures. Most of the pests and diseases such as fruitworm, leaf blight and leaf curling of tomato are common throughout the year, except thrips and whiteflies, which are present only during dry season starting in January, declining in May and ending in June or July depending on the arrival of rain (https://www.bar.gov.ph/index.php/agfishtech-home/crops/207-vegetables/1304-tomato-con-t).

Hence, to provide a suitable environment for tomato crop in which increased yields of high quality produce can be grown, mulching materials has been used for wet season tomato production. This type of crop cultivation, by protecting crops against environmental stresses, can result in stable yields of high quality produce, which sells at a good price.

Mulching is the process of covering the soil/ground to make more favorable for plant growth. (Dalorima L.T. 2014). It minimizes soil erosion and compaction from heavy rains, limits growth of weeds near plants, and indigenous mulch that is derived from plant material will decompose (Nisnisan, 2014). According to Acayen, Mandaraog, Mariano and Rivero, (2005), indigenous mulches also help enriched the soil with nutrients as they breakdown.

According to Bhardwaj (2013), mulching reduces the germination and nourishment of many weeds. The mulching operation favors in the reduction of weed seed germination, weeds growth and keeps the weed under control. In covering or mulching the soil surface can prevent weed seed germination or physically suppress seedling emergence, thus provide effective weed control.

Mulch suppresses weed growth, reduces soil erosion and prevent fruits from touching the soil and eventual rotting. Common observations also indicate that it reduces leaf and fruit diseases during the rainy season. Thus, mulch could ensure good crop yield, economize fertilizer and water use and sustain crop productivity for years without depleting the soil.

According to Kayum 2008, different types of mulch save labor cost for weed control and improves soil physical conditions by enhancing biological activity of soil fauna and thus increases soil fertility which ultimately increases the yield of tomato.

One of the most anticipated effects of mulching in tomato production is on pest control. Hence, this study was undertaken to evaluate and identify the best mulching materials on the control of major pests that could increase the yield and profit of tomato farmers during the WS.

METHODOLOGY

Locale of the Study

The trial was conducted at the experimental farm of the Mariano Marcos State University (MMSU), City of Batac, Ilocos Norte. Based on the Corona classification, the climate of Ilocos Norte belongs to Type 1, i.e., two distinct seasons, wet and dry. Wet season is from May to October. About 90% of the total annual rainfall, averaging 2000mm, occurred within this period. An average of six tropical cyclones visited the area each year, most of which are considered tropical storms (62-117 kph), and typhoons (118-239kph). These tropical cyclones brought heavy rains that usually keep the low-lying areas submerged or waterlogged; and which such conditions do not favor the cultivation of tomato. The application of improved cultural management technique, such as the use of appropriate mulching materials can be one factor that could provide better environment for the test plants during the WS.

Experimental design and treatments

The experiment was laid-out in a Randomized Complete Block Design (RCBD) with three replications. The treatments were as follows: T_1 - Plastic Mulch (PM); T_2 - Dried Grasses (DG); T_3 - Rice Straw (RS); T_4 - Unmulched (UM) (control); T_5 - Sawdust (SD); T_6 - Carbonized Rice Hull (CRH) and T_7 - Rice Hull (RH).

Cultural Management

Recommended cultural management practices based on evaluation trial was strictly followed. A seedbed was prepared and seeds were sown thinly in rows spaced at 5cm, then covered with soil mixture. Daily watering was done in the morning or late in the afternoon. One week before transplanting, the seedlings were hardened by gradually reducing the frequency of watering. Thorough land preparation was employed wherein plowing and harrowing were done alternatively two times. Mulching materials and organic fertilizer were placed before transplanting. Seedlings were transplanted in raised beds three to four weeks after sowing. Raised beds were prepared at 20cm high; width of plots was 1.0m, double row plots were used, 5m long and 0.4m distance between hills. Basal application of 14-14-14 during transplanting was done at the rate of 15g $hill^{-1}$. The first side-dressing was applied three weeks after transplanting (WAT) by mixing two parts urea (46-0-0) and one part muriate of potash (0-0-60). This mixture was applied at the rate of 10g (1tsp) $hill^{-1}$, 6-8cm away from the base of the seedlings. The same mixture was side-dressed two weeks later. Supplemental irrigation was given as the need arises.

Data gathering procedures

Data on the prevalence of pests were gathered 8 WAT. The different weed species were identified, monitored and gathered by using one quadrant sampling per treatment. Persistent weed species in each treatment were identified, oven-dried and weighed. Data on the incidence of insect pests and diseases were gathered based on % infestation and % infection.

Time needed in weeding each treatment was recorded and this was used as basis in the computation of the cost and return analysis. Other data gathered were percent survival, days to first flower, days to maturity which was taken on the number of days to first and last harvestings, plant height at maturity, yield and yield components, cost and return analysis.

The gathered data were analyzed using the Analysis of Variance for RCBD. Treatment means of parameters that showed significant F-test results were further compared using HSD at 5% level of significance.

RESULTS AND DISCUSSION

Effect of mulch on pest incidence

Weed identity and density

The identified weed species in the experimental plots mulched with different mulching materials taken at early fruiting stage of the plants during the WS 2012 to WS 2015 were *Cyperus rotundos* L., *Cynodon dactylon* (L.) Pers, *Chrisopogan aciculatus* (Retz), *Brachiaria mutica* (Forssk), *Amaranthus spinosus* L., *Desmanthus virgalus* L., *Imperata cylindrica* L. (Beau V.), *Corchorus capsularis* L. and *Spanacia oleracea* L.

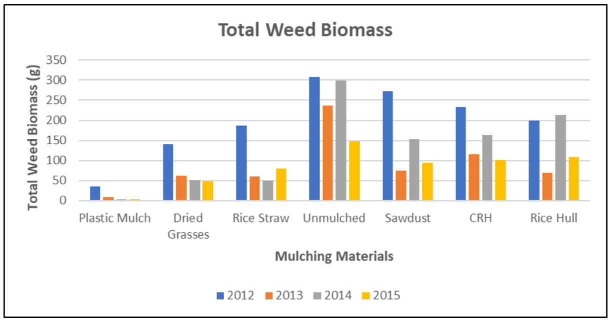

Fig. 1. Total weed biomass in tomato plots mulched with different kinds of mulching materials

Significant interaction effect was also obtained on tomato plants mulched with different kinds of mulching materials planted for four years (Fig. 1). The lowest weed biomass was taken from plots mulched with plastic sheet during the WS 2012-2015 with 36.2g, 9.1g, 4.3g and 3.0g, respectively. This was followed by DG and RS during the WS 2013 to WS 2015 with 47.2g to 80.2g weed biomass. The highest weed biomass was observed from unmulched plots during the WS 2012 to WS 2014 at 308.1g, 236.9g and 299.6g, respectively; followed by the use of SD, CRH and RH.

It was observed that there was higher weed biomass in plots mulched with SD, CRH, and RH especially during heavy rains which easily washed-up these materials.

Vegetable producers have used plastic mulches for at least 40 years to prevent weed growth near the crop, and promote crop yields. Easy mechanical application, cost efficient weed control, and increased crop yields have led to widespread adoption of plastic mulch by organic and conventional vegetable farmers (Schonbeck, 2012). Valipour M., *et al.* (2020) stated that mulches suppress the weeds in crop plants, and remove the residual effects of pesticides, fertilizers, and heavy metals. The selection of mulching material is important with respect to crop type, management practices, and climatic conditions. The appropriate mulching technique could provide the aforementioned benefits to the agro-ecological systems.

According to Babatunde and Etukudo (2015), as cited by Uguajio and Ernest 2014, polyethylene mulches are widely used in vegetable production and have contributed significantly to reduction of losses due to weed competition.

Table 1. Pests in tomato planted with different mulching materials during the WS 2012 to WS 2015

TREATMENTS	TOTAL WEED BIOMASS (g/quadrant)	FRUITWORM DAMAGE (%)	LEAF CURLING DAMAGE (%)	LEAF BLIGHT DAMAGE (%)
Mulching Materials MM)	**	*	**	**
1. Dried Grasses	75.11d	21.11a	26.45b	17.02de
2. Rice Straw	94.87cd	20.45a	18.74e	11.43e
3 Sawdust	147.18bc	22.68a	28.30abcd	27.62cd
4. CRH	149.02b	21.06a	24.98cd	20.35d
5. Rice Hull	153.44b	19.25b	28.36abc	35.48ab
6. Plastic Mulch (ck)	13.21e	21.28a	28.94ab	29.94c
7. Unmulched (ck)	248.26a	22.00a	30.57a	39.25a
Year (Y)	**	**	**	**
2012	196.62a	29.52a	32.83a	28.98ab
2013	89.77c	24.07b	32.15ab	31.50a
2014	133.67b	14.25c	20.68c	20.57c
2015	83.29c	16.63c	20.81c	22.43c
MM:Y	**	**	**	**
CV (%)	5.79	7.57	5.64	7.80

** - significant at 1% level
* - significant at 5% level
In a column, means marked with the same letter are not significantly different using HSD.

In a study done by Gomonet and Cagasan (2020) stated that mulching material such as rice straw, control weeds and enhance the growth and yield of the crop. In another study conducted by Abouziena H. F. and S.M. Radwan (2015), they stated that organic mulch are effective for weed control and could be a potential alternative to synthetic herbicides, hoeing or hand removal of weeds in onion organic farming.

Insect pests

Table 1 also shows the mean data on pests infestation/infection of tomato plants mulched with different kinds of mulching materials, analyzed across years during the WS 2012 to WS 2015. The common pests observed were fruitworm, leaf curling and leaf blight, wherein significant variations were obtained.

There was a significant interaction effect on the tomato plants mulched with mulching materials planted in four years (Fig. 2). The lowest fruitworm infestations were obtained during the WS 2014 (11.52% to 16.64%) and 2015 (9.99% to 18.76%). The highest fruitworm infestation was observed during the WS 2012 and 2013 in all plants mulched with the different mulching materials. This might be attributed to the high amount of rainfall and low bright sunshine which favored fruit worm infestation (Fig. 5 and 6).

Significant interaction effect was also obtained on the percent leaf curling infection of tomato plants mulched with different kinds of mulching materials planted in four years (Fig. 3). The lowest leaf curl infection was observed from plants mulched with plastic sheet during the WS 2013, 2014 and 2015 with an infection of 15.65%, 16.00% and 17.25%, respectively. This was followed by plants mulched with dried grasses (17.00%) and rice straw (18.62%). Highest infection was observed during the WS 2012 and WS 2013 in plants without mulch at 36.75% and 36.92%, respectively. The occurrence of typhoon during the year 2012 and 2013

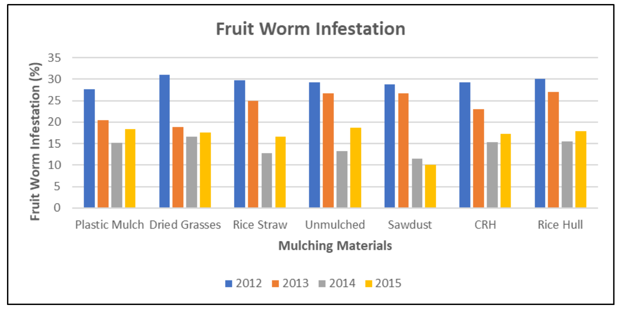

Fig. 2. Fruitworm infestation of tomato plants mulched with different kinds of mulching materials

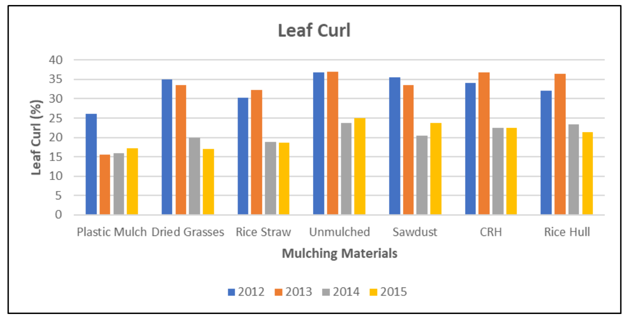

Fig. 3. Leaf curling of tomato plants mulched with different kinds of mulching materials

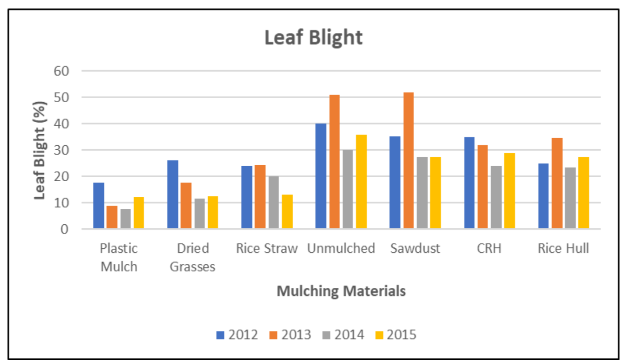

Fig. 4. Leaf blight of tomato plants mulched with different kinds of mulching materials

contributed to the high amount of rainfall in the month of August with 956.3mm and 1006.5mm rainfall (Fig. 5); this condition made the plants susceptible to leaf curling infection.

Significant interaction effect was noticed on the percent leaf blight infection of the tomato plants with different kinds of mulching materials planted in four years (Fig. 4). Plants with plastic mulch had the

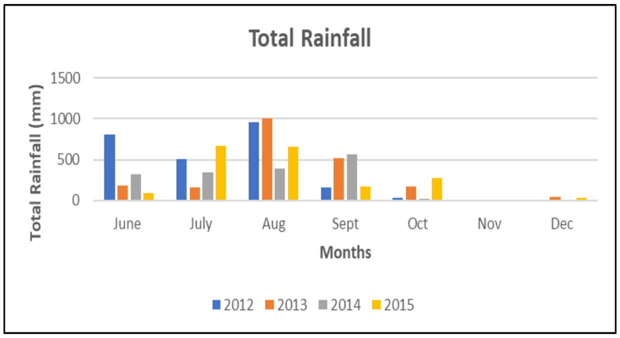

Fig. 5. Total rainfall from June to December 2012-2015 during the growing period of the tomato plants, Agrometeorological Station, MMSU-PAGASA, City of Batac, Ilocos

lowest leaf blight infection in 2014 (7.50%), 2013 (8.70%) and 2015 (12.00%). Lower infection was also observed in plants mulched with dried grasses in 2014 and 2015 at 11.67% and 12.36%, respectively; and in rice straw at 12.95% in WS 2015. The highest leaf blight infection was obtained in plants mulched with sawdust at 52% and plants without mulch at 51%. Sawdust is acidic, making it a good mulch choice for acid-loving plants. As sawdust decomposes, it robs soil of nitrogen, but since sawdust decompose a lot faster, you may have to compensate the addition of nitrogen. Hence, when using sawdust for mulch, growers should take couple simple precautions (https://www.gardeningknowhow.com/garden-how-to/mulch/using-sawdust-as-mulch.htm). Thus, with the presence of nitrogen, it allows the production of blight infection.

Based on the results of the study, some of the different mulching materials used in tomato production were good materials to help the plants to withstand pest incidence. Many non-living materials such as rice straw, dried grasses, sawdust, rice hull, carbonized rice hull have been used to cover the soil in order to prevent insect infestation and weed growth.

Proper combination of management practices and other methods of pest control could be the most logical step in attaining the most economical and effective pest control measure.

Tomato Yield

Significant differences were observed during the WS 2013 and WS 2015 in terms of marketable yield (Table 3). Highest marketable yield per hectare was observed in tomato plants mulched with plastic sheet. However, this was comparable in plots mulched with DG and RS. The lowest were observed from SD and the UM treatment.

According to Mirshekari *et al.*, 2012, as cited by Babatunde and Etukudo (2015), using black plastic instead of bare soil have recorded higher yields, which supported the present results.

During the WS 2012, highly significant differences were obtained, wherein plot mulched with plastic sheet produced the highest marketable yield. This was followed by tomato plants mulched with DG and RS. The lowest were observed from SD and the UM treatment.

It can be noted that DG and RS were good mulching materials in tomato production. High marketable yield was obtained in four consecutive wet season (2012 to 2015). Sufficient amount of moisture was essential for better fruit production of the plants.

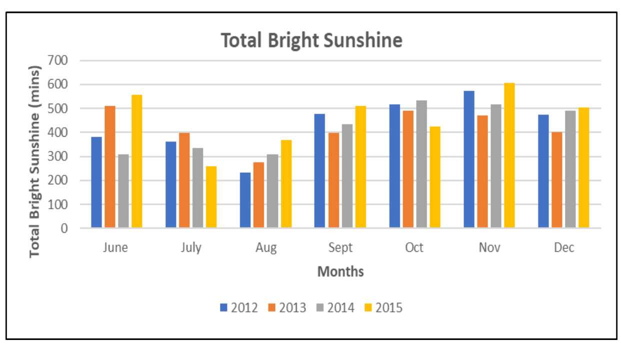

Fig. 6. Total bright sunshine from June to December 2012-2015 during the growing period of the tomato plants, Agrometeorological Station, MMSU-PAGASA, City of Batac, Ilocos Norte

A related study conducted in BPI-Buguias Seedfarm and BPI-Baguio experimental farm shows that mulching dried sunflower leaves in lettuce and broccoli enhanced the production of highest marketable yield (Castillo and Bacayan, 2017). Further, it was noted that its application initiated longer and most number of leaves on lettuce, enhanced production of widest curds on broccoli.

Yield obtained in tomato was comparable during the wet season trials (WS 2012, 2013, 2014 and 2015 trials). High amount of rainfall (323-343mm) favored good growth and development of the plants using all the mulching materials/treatments (Fig. 6). Lower fruit worm infestation during the WS 2014 compared to WS 2012, WS 2013 and WS 2015 (Table 1) might had contributed to the higher marketable yield of the tomato plants.

Commercial tomato growers often use black plastic mulch, it retains heat and usually increases tomato plant growth and yield as compared in plants without the application of mulching materials (control). This plastic

Table 3. Marketable fruit yield of tomato mulched with different materials during the WS 2012 to WS 2015

MULCHING MATERIALS	MARKETABLE YIELD (tha^{-1})				
	WS 2012 **	WS 2013 *	WS 2014 ns	WS 2015 **	Mean
1. Dried Grasses	16.04b	16.6a	50.84	20.14ab	25.91
2. Rice Straw	15.51bc	15.60ab	49.17	21.31ab	25.40
3 Sawdust	12.64e	13.52b	39.67	18.52b	21.09
4. CRH	13.29de	14.03b	43.80	19.65b	22.69
5. Rice Hull	14.41cd	15.29ab	44.02	19.53b	23.31
6. Plastic Mulch	18.46a	16.99a	48.56	24.69a	27.18
7. Unmulched	12.97e	13.22b	39.39	17.35b	20.73
MEAN	14.76	5.06	45.06	20.17	21.26
CV (%)	15.50	23.10	17.80	8.28	

** - significant at 1% level
* - significant at 5% level
ns - not significant
In a column, means marked with the same letter are not significantly different using HSD.

Table 4. Cost and return analysis in tomato production per hectare using different mulching materials

PARTICULARS	DRIED GRASSES	RICE STRAW	SAW DUST	CARBONIZED RICE HULL	RICE HULL	PLASTIC MULCH	UN-MULCHED
A. Labor Cost (P)	42,000	39,500	40,000	41,250	40,000	33,250	48,250
B. Material Cost (P)	98,500	108,000	98,500	98,500	98,500	120,000	98,000
C. Total Production Cost (P)	140,500	142,500	138,500	139,750	138,500	153,250	136,250
D. Average Yield (tha^{-1})	25.91	25.40	21.09	22.69	23.31	27.18	20.73
E. Gross Income @ P20/kg	518,200	508,000	421,800	453,800	466,200	543,600	414,600
F. Net Return (P)	377,700	365,500	283,300	314,050	327,700	390,350	278,350
G. Benefit Cost Ratio (BCR)	2.69	2.56	2.05	2.25	2.37	2.55	2.04

mulch, however, is labor intensive and costly (Patterson Susan, 2016); hence, the use of dried grasses and rice straw is recommended in tomato production.

In an experiment conducted by Inusah, BIY (2013), different types of organic-based mulch such as grass and rice straw used in irrigated onion production significantly improved onion productivity and yields under tropical conditions. Onion bulb mulched with dried grass and rice straw yielded significantly over 60% higher than unmulched.

Profitability of using different mulching materials

Economic analysis of the study indicates that using RS, DG and PM increased marketable tomato fruit yield, hence obtaining a bigger economic returns as compared in the unmulched and other mulching materials.

The labor costs incurred in growing tomato using different mulching materials (Table 4) was lowest with the use of plastic mulch at ₱33,250. Highest net returns, therefore was obtained from tomato mulched with plastic mulch, (₱390,350), followed by dried grasses and rice straw, with net returns of ₱377,700 and ₱365,500, respectively. These data marked a positive effect of using these kind of mulching materials which gave a BCR value of 2.69 (dried grasses), 2.56 (rice straw) and 2.55 (plastic mulch). Black plastic film, effectively suppress most weeds, thereby reducing labor and other costs for weed control (Mark Schonbeck, 2012).

CONCLUSIONS AND RECOMMENDATION

Application of black plastic mulch together with the use of dried grasses and rice straw in tomato production significantly influences plant growth and fruit yield of tomato. Findings show that using black plastic mulch in tomato effectively suppressed weed growth, and reduced labor and other costs for weed control, improved the growing condition for tomato thus improving its competitiveness against weeds.

Farmers who cannot afford the high price of plastic mulch, other mulching materials, such as rice straw and dried grasses could be a good substitute; which produce lesser weed biomass, higher yield and benefit cost ratio as compared to the use of saw dust, rice hull, carbonized rice hull and the unmulched. Satisfactory net return and higher BCR can be obtained from plants mulched with plastic sheet, dried grasses and rice straw. Dried grasses and rice straw are best organic mulching materials in tomato production, and can serve as substitute for plastic mulch, and are recommended for farmers because these effectively suppress weeds, can withstand pest incidence, thus, obtaining higher yield and income.

LITERATURE CITED

Abouziena, H.F. and Radwan, S.M. (2015). Allelopathic Effects of Sawdust, Rice Straw, Bur-clover Weed and Cogongrass on Weed Control and Development of Onion. International Journal of ChemTech Research CODEN (USA): IJCRGG ISSN: 0974-4290 Vol.7, No. 01, pp. 337-345.

Bhardwaj R.L. and Kendra, K.V. (2013). Effect of Mulching on Crop Production under Rainfed Condition. M. P. University of Agriculture and Technology. India. 188-197.

Babatunde, T.J. and Etukudo, O.O. (2015). Response of Tomato Variety (Roma F) Yield to Different Mulch Materials and Staking in Kabba, Kogi State, Nigeria. Journal of Agricultural Studies.

Castillo, H.B. and Bacayan, J.J. (2017). Evaluation of Organic Mulching Materials on Selected Highland Vegetables. In bpi. da.gov.ph › bpi › current-publications › e-journal

Dalorima L.T. (2014). Effects of Different Mulcing Materials on the Growth Performance of Okra in Maiguguri.http:/ dx.doi.org/10.14303/irjas.2014.037.

Goitom, T., Tsegay, A. and Abrha, B. (2017). Effect of Organic Mulching on Soil Moisture, Yield, and Yield Contributing Components of Sesame (Sesamum indicum L.). Research Article. Volume 2017 |Article ID 4767509 | https:// doi.org /10.1155/2017/4767509

Gomonet G.M. and Cagasan, U.A. (2020). Growth and Yield of Peanut (Arachis hypogaea L. var. NSIC Pn15) as Influenced by Different Thickness of Rice Hull and Rice Straw Mulch. Department of Agronomy, Visayas Visayas State University, Visca, Baybay City. International Journal of Nature and Life Sciences. e-ISSN: 2602-2397 Vol. 4(1), June, pp. 47-55

https://www.bar.gov.ph/index.php/agfishtech-home/crops/207-vegetables/1304-tomato-con-t.AgFishTech Portal

Https://www.gardeningknowhow.com/garden-how-to/mulch/using-sawdust-as-mulch.htm

Gardening know how: sawdust for garden use – tips for using sawdust as a garden mulch :

IFOAM - Organics International. (2015). Mulching in Organic Agriculture, The Philippines. The International Federation of Organic Agriculture Movements. Country of first practice Philippines ID and publishing year 8365 and 2015 Sustainable Development Goals.

Inusah, I.B., Wiredu, A.N., Yirzagla, J. and Mawunya, M. (2013). Effects of Different Mulches on the Yeld and Productivity of Drip Irrigated Onions under Tropical Conditions. International Institute of Tropical Agriculture.

von Diest, J. and Addison, P. (2016). Are Mulches Useful for Integrated Pest Management? in https:// www.wineland.co.za/mulches-useful-integrated-pest-management.

Kaur, C. and Kapoor, H.C. (2008). Antioxidant Activity in Tomato a Function of Genotype in: Preedy, RV, Watson RR (eds). Tomatoes and Tomato Products. Nutritional, Medicinal and Therapeutic Properties, Science Publishers, Enfield New Hampshire 03748. United States of America pp111-132.

Kayum, M.A., Asaduzzaman, M. and Haque, M.Z. (2008). Effects of Indigenous Mulches on Growth and Yield of Tomato. Journal of Agriculture and Rural Development. Bangladesh.

Kelley, W.T. and Boyhan, G. (2010). Commercial Tomato Production. Hand Book. The University of Georgia and Ft. Valley State University.

Lutap, L.A. and Atis, M.I. (2013). Pest Management in Vegetable Production: The Case of the Rainfed Lowlands in Ilocos Norte. MMSU Science and Technology Journal ISSN: 2012 0060 Vol. 3. No. 1.

Nisnisan, B.M. (2014). Performance of Tomato Plant as Affected by Organic Mulching Presented at DLSU research Congress 2014 De la Salle University, Manila, Philippines. www.dlsu.edu.ph/ conferences/dlsu_research_congress/… SEE_1V_033_FT.pdf.

Patterson, S. (2016). Mulching tomato plants: what's the best mulch for tomatoes.

Prem Ranjan, G.T., Patle, M.P. and Solanke, K.R. (2017). Organic Mulching-A Water Saving Technique to Increase the Production of Fruits and Vegetables. Current Agriculture Research Journal, Ranipool, Sikkim, India. Vol 5, No. 3.

Schonbeck, M. (2012). Synthetic Mulching Materials for Weed Management. Virginia Association for Biological Farming. Organic Agriculture.

Tegen, H., Dessalegn, Y. and Mohammed, W. (2016). Influence of Mulching and Varieties on Growth and Yield of Tomato under Polyhouse. Journal of Horticulture and Forestry.

Valipour M., Saleem, M.F., Zaheer, M.S., Ahmad, S., Haider M., Aslam , M.U. and Nazar, M.A. (2020). Potential Agricultural and Environmental Benefits of Mulches - A Review. Bulletin of the National Research Centre. Department of Agronomy, University College of Agriculture & Environmental Sciences, The Islamia University of Bahawalpur, Bahawalpur, Pakistan, Volume 44, Article number: 75.

Research Directorate
Mariano Marcos State University
City of Batac 2906 Ilocos Norte, Philippines

email: rddirectorate@mmsu.edu.ph
telephone: (077) 600-0459
website: http://research.mmsu.edu.ph
email: rddirectorate@mmsu.edu.ph