

# The Growth of the Watermelons with Geometric Shapes and Comparing Retention between Cubic and Hexagonal Forms

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**Abstract**—Shape and form of the watermelon fruits are important factors to save spaces and reducing damage during storing of the fruits. In order to save spaces and prevent fruit damage in watermelon the following experiment was carried out in the farm. The fruits were boxed when they were approximately one cm less than the box diameter. The cubic, hexagonal forms were compared in this research. To do this, different boxes were designed with different holes on the sides to holes the watermelons fruits for shaping. The shapes of the boxes were hexagonal and cubic. The boxes holes sizes were the same with 10mm diameter each. Each side of the boxes had different holes including: without holes to 75 holes. The result showed that the best shape for watermelon storing to save space and prevent fruit damage was hexagonal form. The percentages of the fruit damage were 33 to 80 respectively.

**Keywords**—Cubic form, fruit damage, hexagonal, watermelon shape.

## I. INTRODUCTION

**W**ATERMELON (*Citrullus lanatus*) belong to *Cucurbitacea* family require a long, warm growing season the variety is *Crimson Sweet*. In order to FAOSTAT 102,889,076.00 ton at 2011 was produced. IRAN had 3,250,000.00 ton in this year [1]. Watermelon was first harvested in Egypt 5,000 years ago [2]. There is 1,200 varieties of watermelon grown in 96 countries. It grow best under temperatures of 21 to 29°C, tolerating temperatures up to 32°C [3]. The plant also tolerates high humidity [4]. Although watermelons are produced on a number of soil types, the crop does not do well on muck soils [5]. The optimum pH range for watermelons is 6.0 to 6.5, although the plant will tolerate soils with pH as low as 5. Watermelon production is also affected by soil temperature. Seedlings are easily damaged by frost, and germination is very slow when soil temperature is less

than 21°C [6], [7]. Melons have historically been preferred during the summer picnic season. June and July are the primary months, accounting for 40 percent of the annual supplies [8].

To show a profit, a grower must produce good yields of high-quality melons, something that can be obtained only with careful management. [9]

Fruit shape and appearance are quite varied, ranging from round to cylindrical and a single color to various striped patterns on the fruit surface. Watermelon fruit is very large, smooth and oval to round. The skin can be solid green or green striped with yellow. The edible flesh is usually pink with many flat, oval, black seeds throughout [10].

Symptoms of *Phytophthora* fruit rot begin as a water-soaked, often depressed and spot. Frequently, the area of the fruit in contact with the moist ground is affected first, but symptoms also can develop on the upper surface, following rain or overhead irrigation which provides splashing water to disperse the pathogen. In older lesions, a mass of white mycelium that contains sporangia may develop. Infected fruit can decay rapidly and collapse. Fruit decay may continue after harvest. *Phytophthora* fruit rot is caused by *Phytophthora capsici* and other *Phytophthora* sp [10].

Management of soil moisture by selecting well-drained fields, avoiding low-lying fields, and not over irrigating is an effective management strategy [11].

Sun scald (burn) results from exposure to intense solar radiation that leads to dehydration and overheating damage of the rind tissue. Sun scald can be alleviated by covering the fruit with vines or straw material. Sunburn occurs most frequently in varieties that have dark-green rinds. Charleston Gray types and other melons with grey-green rinds rarely suffer from sunburn. Good, healthy foliage will minimize sunburn damage as well as favor good yields and quality. Strong winds can blow unprotected vines away from the developing fruit along the edges of the rows and cause full exposure of the fruit to the sun. Loss of foliage covering the melons can increase sunburn. Exposed melons should be covered with vines, straw, or excelsior as they start to mature to prevent sunburn. Each time the field is harvested, the exposed melons must be re-covered. Most fields are picked at least twice. The tops of the containers should be covered to prevent sunburn in transit. Watermelon sales usually are based upon a 1% to 2% shrink, because of breakage. The buyer is responsible for supplying bins and lids or the shipper will send a bill for the cost of these items [12], [13].

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## II. STORAGE

Temperature management is important for optimum watermelon quality. The optimum storage temperature for melons is 15.6°C. Transit temperatures of 12.8° to 22°C with ventilation are recommended. Whole watermelons should not be refrigerated. Watermelons are not adapted to long-term storage. Normally the upper limit of suitable storage is about three weeks. However, this will vary from variety to variety. Storage for more than two weeks triggers a loss in flesh crispness [14]-[16]. Storing melons for several weeks at room temperature will result in poor flavor. However, when fruit is held just a few days at warmer temperatures, the flesh color tends to intensify. Sugar content does not change after harvest. Watermelons' flesh will tend to lose its red color if held too long at temperatures below 10 °C [17].

## III. MATERIALS & METHODS

The following steps were carried out to shape the watermelon fruits:

### A. Planting



Fig. 1 Farm of watermelon

This experiment was carried out in a farm of the higher educational center (ihc) in Karaj close to Tehran. The region's climate is relatively temperate. The planting and harvesting was done by students of (ihc) and was supervised by the farm manager. In order to prevent moisture damage for fruits they were slightly than the others. Watermelon variety *Crimson Sweet* seeds which are more suitable to this climate were sowed on the rows with 100cm and 70cm from each other in 25, April, 2012. They also have relatively thin skins which make them easier to form. The plants were irrigated

once a week. At first while the weather was cooler the irrigation was each 7-8 days, but during the July and August in warmer weather it is done each 5-6 days. Unfortunately, unexpected rainfall for two times that occurred in this period, leading to increased downtime on watermelons.



Fig. 2 The growth stages

### B. Shaping

Fruits were boxed before reaching to the box sized diameter (approximately one cm less) in 10-15 July.

Preliminary experiments with Glass, Wood, Concrete, Transparent Plastic and Plexiglas showed that the best material for Boxes was polycarbonate which is a long life material. Surely a shatterproof material that is 30 times stronger than glass and 12 times stronger than "Artylic". ARTYLIC is a kind of a hard and transparent plastic that made by polymerized of acrylic acid esters. Polycarbonate does not break. But the pressure from growing watermelon fruit makes the box separated from the seams too slowly. Although the Wooden boxes were cheaper, but they changed the color of watermelon skins due to lack of sunlight. The cubic die weight design 1/335 kg and hexagonal weight 1/172kg. Boxes allow water and excess moisture to get off. In order to ventilate properly several holes were installed on boxes sides. It is important to note that the over number of ventilation holes on the surface of the box, caused body frame too weak and likely to break it. Templates to ensure consistency holes diameter 10mm and thickness of 8 mm was considered. The number of holes in each frame was from zero to 75 with the same diameters were also investigated to observe the effect of aeration (skin respiration) on fruit skin. This experiment was carried out in a factorial completely random design with two factors: A. number of holes (including: no ventilation or without any holes, low ventilation, 10-25, medium ventilation 25-50 and high ventilation 50-70 holes per box surface) and B. shape of box including cubic and hexagonal with eight treatments and three replications.



Fig. 3 Some of die with different shapes & materials

In order to drain extra water caused by skin evaporation, which can lead to rot watermelon, some of 3-4 mm holes were

made in the bottom of frames. Since the strength of the box is very important, the boxes were designed and assembled by the students. Immature watermelon fruits were boxed as soon as they reached approximately 1-2cm less than the box size. Boxing the fruits sooner than that, they were damaged due to higher temperature of greenhouse effects in the boxes. In order to reduce sunshine, the boxes were shaded by cut plants or papers. On the other hand later, was not possible to box the fruits. The fruits were constantly monitored every day. The conditions provided for both cubic and hexagonal shapes were same.



Fig. 4 Watermelon fruits in die during the growth

#### C. Harvesting

After shaping the fruits properly, they were removed from the top end of the box. The best time of harvesting fruits was when all of the box corners were almost filled. Of course it will be better and faster for hexagonal form, because it is closer to its natural form, spherical. Watermelons were harvested about 60-80 days after planting. They were about one fourth of this time in box. As the symptom of watermelon fruit ripening is blackened stem junction, so staying more than that caused to more damage.



Fig. 5 Two rows of formed fruits

#### IV. RESULTS AND DISCUSSION

The statistical model is:

$$y_{ijk} = \mu + \delta_i + \delta_j + \delta_{ij} + \varepsilon_{ijk}$$

where:

$y_{ijk}$ =Observations

$\mu$ = Mean

$\delta_i$ = Effect of shape

$\delta_j$ = Effect of number of holes (ventilation)

$\delta_{ij}$ =Interaction effect

$\varepsilon_{ijk}$ =Error

The factorial test incompletely random design has done in with SPSS software, by GLM procedure analyze and compare means of different groups in Duncan method.

TABLE I  
ANALYSES OF VARIANCES

Source	SS	df	MS	F
Corrected Model	6533.292 <sup>a</sup>	7	933.327	32.701
Intercept	76727.042	1	76727.042	2688.247
No.Hole	5706.458	3	1902.153	66.645**
Shape	782.042	1	782.042	27.400**
No. Hole * Shape	44.792	3	14.931	0.523 <sup>ns</sup>
Error	456.667	16	28.542	
Total	83717.000	24		
Corrected Total	6989.958	23		

The results Table I revealed that there are significant differences between the treatments including shapes and number of holes per frame surface.

TABLE II  
DUNCAN TEST FOR MEANS CLASSIFIED BY NUMBER OF HOLES

Level of (ventilation)	No. Hole	N	mean	Std. Error	CV%
1. no ventilation	0	6	80.1667 <sup>a</sup>	3.18	9.7
2. Low	10-25	6	60.0000 <sup>b</sup>	4.26	17.38
3. Med	25-50	6	45.6667 <sup>c</sup>	2.9	15.5
4. High	50-75	6	40.3333 <sup>c</sup>	2.45	14.92

The results in the Table II shows that as the number of holes per boxes increased the fruit damage decreased. But there is no significant difference between L3 and L4. It means that increasing the number of holes causing to higher ventilation resulted to less the fruits damage.

TABLE III  
DUNCAN TEST FOR MEANS CLASSIFIED BY THE FRAME SHAPES

shape	Mean	Std. Error	CV%
1- Cube	62.259 <sup>a</sup>	5.02	27.91
2- Hexagonal	50.83 <sup>b</sup>	4.74	31.83

The results in Table III show that the shape of boxes has significant effect on fruit damage in this experiment. Hexagonal significantly was better than cubic shape in the case of fruit damage.

As the most researches have been carried out on cubic geometric form, this research is going to find out a new hexagon form.

For choosing hexagon between the other polygons there are many reasons, but for better explanation it is inspired by beehives structure. Bees have been designed with an inbuilt ability to build perfect hexagonal shapes which have been shown to be the most efficient use of space. It also makes the comb very



strong. Two reasons First, bees want to enclose the largest possible space with the least amount of wax. Because hexagons are the shape with the most sides that “tessellate”. In other words, if is put a bunch of hexagons next to each other there will be no spaces between them. No shape with more than six sides will do this. Why bees build complex patterns like hexagons for their honeycombs when simpler patterns like circles, triangles and squares are an option. According to the beeologists research, bees are masters of navigation, communication and engineering, making use of all sorts of natural phenomena or laws. One of those laws is the geometric truth that the largest number of sides that will fit together with leaving gaps is six, making the hexagon a popular shape throughout nature and specifically in the honeycomb. Bees achieve the functional configuration of the comb by creating each cell as a simple cylinder and allowing the force of pressure from close packing to flatten the round shape to the more efficient hexagon. It is something similar to what happens to bubbles when they get together. Isolated bubbles are spherical but have a flat side where they stick together [18]-[21].

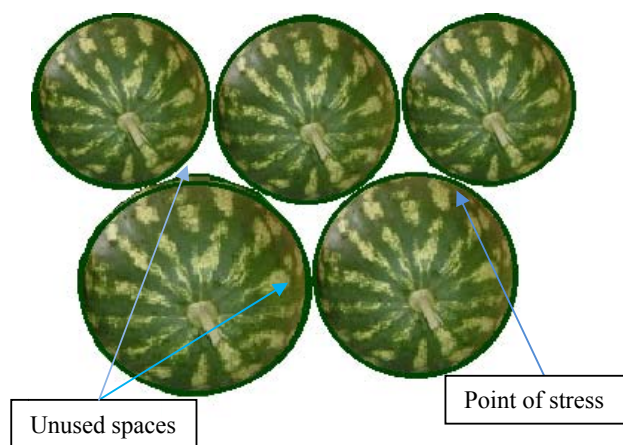


Fig. 6 The spherical watermelon

The spherical natural forms of watermelons occupy a large amount of spaces to store. The new form not only saves the space (in natural form) but also it prevents fruits from damaging. In addition to save the space, it also has different sizes diameter it caused the most damaged rather than other shapes. There is one point of stress concentration. The maximum crush cause to fruit damage is on the contact point. The contact points in cubic form is much more than the spherical form, so less pressure is on fruits, because every dimension is exactly the same as the next one. The better shape after cubic form is hexagonal form. This arrangement is similar to bee hive. The only waste spaces in the latter form are at the angles.

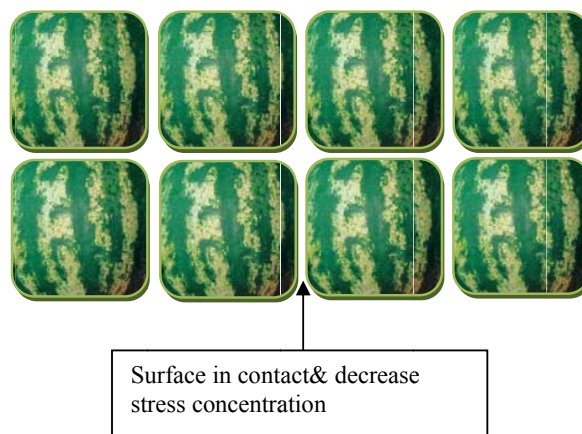


Fig. 7 The cubic watermelon

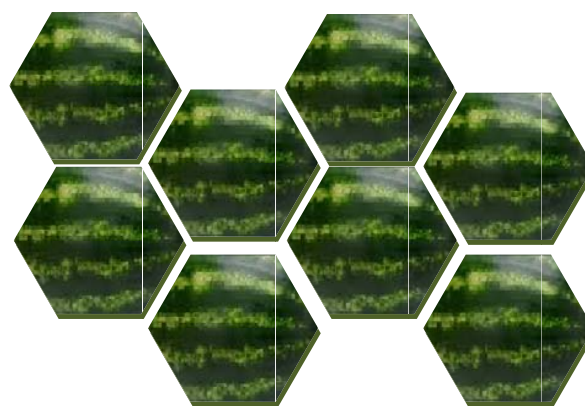


Fig. 8 The hexagonal watermelon

In order to measure the surface of the decade watermelon's skins meshed paper with on mm diameter square 74% was used the paper was completely attached to the skins where it was decade, then by counting the square mm of the paper the surface decade was measured.



Fig. 9 Compare cubic &amp; hexagonal fruits

To make better results of retention the different number of holes tried. So we made a box without any holes. This kind of box made fruits corrupt. In the same time we try different number holes. In four level: 0- no ventilation, 1- low 2- medium 3- high ventilation.

This diagram shows that the least damage in belong to boxes with 75 holes. Surly it can be more than this number, but according to the box size it is the best rate.

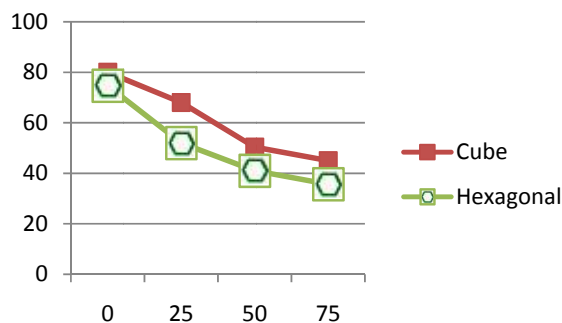


Fig. 10 The rates of damage percentage to the number of holes

TABLE IV  
THE PERCENTAGE OF DAMAGE IN DIFFERENT SHAPES

No holes	Cube	Hexagonal
0	80	74.67
25	68	52
50	50.33	41
75	45	35.67



Fig. 11 (a) Lack of ventilation (b) Sunburn

In this project impact of factors such as lighting, aeration, material and mold to grow watermelon has been investigated. After the growing number of watermelon that was observed in those with fewer holes were most affected by corruption factors and destroyed. Templates that were exposed to direct sunlight were also sunburned. Horizontal formats were also more corrupt.

#### V.CONCLUSION

In this investigation it was concluded that for watermelon storage the best shape was hexagonal having medium ventilation (with 25-50 holes) that it does not have different significant by high ventilation (with 50-75 holes). The percentage of damage fruits significantly decreased as the number of holes in the boxes increased (from 33% to 80%).

#### ACKNOWLEDGMENT

The authors would like to thank these students that helped in farm: Shariati Sounghori, Afkhami, Haj Hasani, Bazregari, Molaee, Zamani, Kababayan. Mr Sanei the farm manager of center. Mr Beheshti, the Instructor of (IHEC) for statistical procedure. Mr Rahimi The head of Mechanization Department, Mr Mokhber the manager of Imam Higher Education Center (IHEC).

#### REFERENCES

- [1] <http://faostat.fao.org>
- [2] <http://watermelonbenefits.com>
- [3] S. Mustapha Iran Manesh- Morteza Malek Yarand. (2011). Post-harvest physiology (fruits & vegetable)
- [4] Spreen, T.H., VanSickle, J.J., Moseley, A.E., Deepak, M.S., and Mathers, L. (1995). Use of Methyl Bromide and the Economic Impact of Its Proposed Ban on the Florida Fruit and Vegetable Industry. University of Florida, Agricultural Experiment Station, Institute of Food and Agricultural Sciences, Gainesville, Florida.
- [5] Personal communication with Donald Maynard, Horticultural Scientist, University of Florida, Gulf Coast Research and Education Center, Bradenton. 2003.
- [6] Johnson, F.A. (1992). Pollination. Pp. 9-10 in Maynard, D.N. (ed.), Watermelon Production Guide for Florida. SP-113, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida.
- [7] Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, The University of Georgia College of Agricultural and Environmental Sciences and the U.S. Department of Agriculture cooperating. January 2000
- [8] Bertelsen, D., Harwood, J., Hoff, F., Lee, H., Perez, A., Pollack, S., and Somwaru, A., and Zepp, G. (1994). Watermelons: An Economic Assessment of the Feasibility of Providing Multiple-Peril Crop Insurance. Prepared by the Economic Research Service, USDA in cooperation with the University of California for the Federal Crop Insurance Corporation.
- [9] Maynard, D. M. & Hochmuth, G.J. 2006. Knott's handbook for vegetable growers. 5th edition.
- [10] McGovern, R.J., J.P. Jones, D.J. Mitchell, R.A. Pluim, and P.R. Gilreath. 1993. Severe outbreak of phytophthora blight and fruit rot of cucurbits in Florida. Phytopathology 83:1388 (abstr.).
- [11] McGovern, R.J., P.D. Roberts, T.A. Kucharek, and P.R. Gilreath. 1998. Phytophthoracapsici: New problems from an old enemy. Proc. Fla. Tomato Inst. Univ. of Fla. PRO 111:9-16.
- [12] Lamont, W. J. Jr., Orzolek, M.D., Harper, J.K., Jarrett, A.R. & Greaser, G.L. 2002. Agricultural alternatives: Drip irrigation for vegetable production. Penn State Cooperative Extension: University Park.
- [13] Orzolek, M.D., Greaser, G.L. & Harper, J.K. 2010. Agricultural Alternatives: Commercial vegetable production guide. Penn State Cooperative Extension. The Pennsylvania State University.
- [14] Roberts, P.D., McGovern, R.J., Kucharek, T.A., and Mitchell, D.J. (2001). Vegetable Diseases Caused by Phytophthoracapsici in Florida. Plant Pathology Department SP 159. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/VH045>
- [15] 67. Roberts, P.D. and McGovern, R.J. (1998). Phytophthora blight causes significant losses to spring vegetable crops. Citrus & Vegetable Magazine 62(11):8-11.
- [16] 68. Somodi, G.C., Jones, J.B., Hopkins, D.L., Stall, R.E., Kucharek, T.A., Hodge, N.C. and Watterson, J.C. (1991). Occurrence of a bacterial watermelon fruit blotch in Florida. Plant Disease 75:1053-1056.
- [17] S. Mustapha Iran Manesh- Morteza Malek Yarand. (2006). Cold Storage & Stocking the food stuffs Vol(1): fruits & vegetable.
- [18] Morgan, F. 1999. The hexagonal honeycomb conjecture. Transactions of the American Mathematical Society 351(May):1753.
- [19] (1991). Shapes and structures and their influence on our world. Toronto: Grolier Ltd. ISBN 0-7172-2782-0.
- [20] Sheldrick Ross, C. (1992). Circles: Shapes in math, science and nature. Toronto: Kids Can Press Ltd. ISBN 1-55074-064-4.
- [21] Voderman, C. (1996). How math works: 100 ways parents and kids can share the wonders of mathematics. London: Dorling Kindersley Ltd. ISBN 0-89577- 850.