"Agribusiness Essential for Food Security: Empowering Youth and Enhancing Quality Products"

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Investigating the level of Interest in the Implementation of Nanoscience as a vehicle toward enhancing food quality and security in the Bahamian agricultural sector

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Abstract

The enhancement of food quality is one of the major areas of concern for those parties pursing higher levels of food security. It is because of this that nations around the globe invest heavily in projects that advance the current sphere of technological possibility. With regards to this, few areas are so closely watched as the advancement of nanotechnology. Nano science, which is being called the industrial revolution for the modern era, has the potential to increase quality of crops and food production in a number of ways. It is because of the many prospective applications for nanotechnology to increase agricultural productivity, in small island developing states (SIDS) such as The Bahamas can benefit greatly from the implementation of these new techniques. In order to pave the way for the use of these techniques, we recognized the need to assess the current level of awareness, understanding and interests in nanotechnology among Bahamians associated with the agricultural sector. We expected limited interest and knowledge about nanotechnology among these individuals due to low level of investment in The Bahamian agricultural sector which has led to technological stagnation and disinterest. We employed a mixed method research approach in order to maximise the conclusiveness of our results. The surveys and interviews conducted support the notion that there is limited knowledge about nanotechnology currently in The Bahamian field of agriculture but also there is an underlying interest in learning that is fuelled by the near unanimous wish to see crop quality improvement.

Introduction

Developing nations such as The Bahamas have battled to achieve greater levels of autonomy for as long that they have existed. There a few concepts that represent true independence than adequate levels of food security. According to The World Food Summit of 1996, food security was defined as existing "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life" (Food and Agricultural Organization of The United Nations 1996). This idea of food security stems around a persons' ability to physically and economically gain access to food of both nutritional significance as well as to the individuals' preference. The Bahamas, like many of other developing nations, imports the majority of the food it consumes and has constructed its economy heavily around the service sector with heavy emphasis being placed on the tourism and banking industries. The Bahamas roughly spends 250million dollars annually on the food items that it imports which represent over 80% of nation's food consumption (Michigan State University 2010). Currently, agriculture only represents 2.7% of the total national GDP and 5% of the labour force (CIA 2012). There are currently no major agricultural operations in The Bahamas, with the last major agricultural operations shutting down in 2005 due to widespread incidence of citrus canker resulting in revoking of export of citrus privileges. The focus of The Bahamian school system on service based professions has also contributed to a large void forming in the

agricultural sector. This service based economy can perhaps be traced back to The Bahamas colonial past and is by no means a new issue for many nations in the Caribbean. The British colonizers realized that The Bahamas had set upon the unproductive path of limited food independence. A memorandum of the Colonial Secretary read in 1930,

We [Colonial Office] cannot be blind to the fact that the productivity of the Colony has diminished nigh to vanishing point and that The Bahamas stand almost alone among the British Colonies as a territory that has gone back rather than forward in productivity and contribution to British trade. Retrogression has in late years gone so far that the Colony now imports even more tropical fruits and a part of the staple food supply to the mass of the people. That might be no very consideration if the populace had other available means of subsistence, but in point of the fact the opportunities of the people to earn their living have diminished rather than increased" (Eneas 1999).

This is an extremely daunting proposition, especially in the context of the modern Bahamas which has regressed, as this problem has only increased in terms of imports. Another major issue that the Bahamian agricultural sector has faced over the years is the fact that majority of the practicing farmers are rapidly aging and still continue to practice increasingly outdated and inefficient farming methods. This coupled with little to no farming records being kept by the average farmer has allowed the sector to remain stagnant and ill equipped to handle the demands of food security in The Bahamas with an increasing population. It is because of these demands that it is imperative to pursue technological efficiency such that the food production process becomes easier. One of the most revolutionary breakthroughs of the modern day life is man's ability to increase his domain of manipulation. Few of these frontiers are as new and exciting as the field of nanotechnology. Nanotechnology involves the study of vastly small substances and the manipulation matter on the nano or billionth of a meter scale. This enables Nano scientists to, for example, place one atom next to another, and create stronger bonds between elements thus giving rise to new and more favourable characteristics.

In the late 1970's, Eric Drexler began to invent what would become molecular manufacturing. He quickly realized that molecular machines could control the chemical manufacture of complex products, including additional manufacturing systems-which would be a very powerful technology. Drexler published scientific papers beginning in 1981. In 1986 he introduced the term "nanotechnology" in his book *Engines of Creation* to describe this approach to manufacturing and some of its consequences. (Subsequent search showed that Taniguchi had previously used the word "nano-technology" in Japan to describe precision micromachining.) In 1992 Drexler published *Nanosystems*, a technical work outlining a way to manufacture extremely high-performance machines out of molecular carbon lattice ("diamondoid"). Meanwhile, he was also engaging in policy activism to raise awareness of the implications of the technology; he founded the Foresight Institute in 1986 (Phoenix 2008).

In terms of agricultural applications, it has been predicted that by 2010, nanofood products worth $20 billion may be on the market (Downey 2006). There are many applications for nanotechnology in areas such as packaging as they can be used to produce safer pathogenic barriers. They can also be used in detection of disease causing agents. Nanotechnology can be used to enhance crop quality in ways such as performing as efficient vehicles of pesticide transport. Naturally-occurring biopolymers and other biological molecules of nanosize scale, such as oligosaccharides or polysaccharides and proteins, can be used for the encapsulation of vitamins, prebiotics and probiotics formulations, and for drug-delivery systems or nutraceuticals (Sozer and

Kokini 2009). The most cost-effective applications of nanotechnology in the food industry are currently in the areas of novel functional materials development, food fortification and formulations, food processing at both micro and nano scale levels, food product development, and storage" (Tarver 2006). All over America $2 billion is being invested annually in nanotechnology developments around the world, with nearly 40% of this in the USA. Japan is a major contributor, as are the European Governments and major industrial economies such as Singapore, Taiwan, China. The key to making nanotechnology a feasible everyday agricultural solution is further research and development coupled with education of the public on its processes to they become more accepting advocates of its applications.

Literature Review

Food security is one of the major areas discussed with in the field of agriculture. Many sources defined the term food security as the ability for all members of a country to have access to sufficient, safe, nutritious food to maintain a healthy and active life at all times. With this being said, food security is without a doubt at mercy to a number of environmental factors that can contribute to decrease foods' "safeness". Over the years, scholars have introduced an array of ground breaking methods and techniques within the agricultural field to enhance the safety. Of these, the implementation of nanotechnology has made its mark in different aspects, such as packaging and processing that prove to be vital for the maintenance of food sources. Small Island Developing States (SIDS), like The Bahamas are at risk to a breach in food security due to their heavy reliance on imported food items from around the world. The following articles will discuss the possible benefits of an agriculture sector fortified with Nanoscience implementations.

Upon discussing food security, two separate articles that discussed the limitations of food security looking at it from different perspectives. The argument presented by Pinstrup-Andersen, seek to uncover the methods used to measure food security (2008). How exactly is food security measured? The usage of the subjective word "sufficient" used in the definition does not fully give a concise meaning to what food security is. The author related the definition of food security with real world examples to overall decrease the feasibility of the present definition. The author continues to suggest that "food preferences" should be taken into consideration where as a country is a said to exhibit adequate food security. The interpretation of "preferences" to mean: the acquisition of foods that is socially and culturally acceptable and also consistent with religious the religious and ethical values of the people. Further into Pinstrup-Andersen's argument, there was mention made on the significance of how household maintenance plays a role in food security. A household is considered secure when its members have the ability to acquire food to meet their individual nutritional value. This is also not a static figure as the nutritional requirements for different individuals vastly differ. Furthermore, the extent to individual food security is dependent on non-food factors like proper sanitation, water quality and access to primary health care (Pinstrup-Andersen 2009).

In Beddington's article (2009), the focus was not on the definition, rather the factors that contribute to fluctuations of food security. Notable factors include the supply and demand system, climate change, government policies, population increase and urbanization. These hindrances are somewhat naturally occurring, however the efficiency and responsiveness of the government to instil proper polices can easily circumvent food security related issues. Similar to Pinstrup-Andersen's (2009) article, the natural progression of increase in population can consequently contribute to a countries' own decrease in food security.

With agriculture being the main interface

between humans in the environment, this lead to an uprising of drastic climatic changes along with ecosystem degradation (Srilatha 2011). Fertilizer usage as a means to fortify soil and pesticide usage as a means for crop protection has been the staple of modern technologies that contributed to crop improvement.

An additional four articles were reviewed that stated the current and future usage of nanotechnology. A guaranteed method to improve crop quality and in turn food security, is by the execution of nanotechnology in some fashion in the agricultural field (Beddington, J. 2009, Srilatha 2011 and Weiss et al 2006).

Even thought nanotechnology is a maturing field, currently there are methods where nanoparticles contribute to the overall health of crops by combating diseases (Srilatha 2011). With nano being on the one billionth scale, nanotubes create instances where there can be a manipulation of living cells (Beddington, J. 2009 and Weiss et al 2006). Further implications involve the nanotubes and nanocapsules that act as vehicles to deliver desired molecules or genes into the seeds during germination that can protect them from the diseases (Beddington, J. 2009 Srilatha 2011 and Weiss et al 2006). The Mesoporous Silica Nanoparticles are often referred to as “magic bullets”, seeing that they possess the ability to release herbicides, chemicals or genes on specific areas of the plants anatomy.

Other implications of nanotechnology that can be beneficial are electrochemical biosensors with exponential sensitivity to detect minute amounts of contaminants like viruses, bacteria and toxins and can effective immobilize said pathogens in a controlled manner (Srilatha 2011).

Even with the greater application of nanotechnology to be just over the horizon, there are still limitations addressed in the articles for the progression of this new technology due to concerns of the public and different government agencies. Siegrist (2008) conducted a survey in the German speaking part of Switzerland to research the general acceptability and concerns about products derived from nanoagriculture. The results clearly stated a majority negative vote however, a limitation that was not clearly outlined was the fact that there where dated applications of nanotechnology used in the questionnaire. Furthermore there was a mean age of 52.8 between 337 individuals. There could have been a potential age bias that contributed to the negative perception seeing that newer, safer and revolutionary method s have been broadcasted more recently.

The article authored by Weiss (2006) presented an unbiased approach to the nanotechnology issue. Even with the large number of potential applications of nanotechnology within the food industry; however, many of these may be difficult to adopt commercially because they are either too expensive or too impractical to implement on an industrial scale (Weiss et al 2006). Weiss continues to mention that the Institute of Food Science and Technology (IFST), based in th UK recommends that nanoparticles be treated as new, potentially harmful materials until testing proves their safety (2006).

Upon review of all the articles, there were frequent references to the vast, ground breaking technological advances that would arise from continual research in the nano field. All articles gave interesting application of Nanoparticles in the scope of life however the limitations discussed made the application to Small Island Developing States (SIDS), somewhat less feasible.

Methodology

In order to gain the necessary understanding of the potential interest in The Bahamian Agricultural sector simple surveys were administered to those determined to be involved with the agricultural sector as well as members of the general public. These qualification ranges included farmers, lab technicians, agricultural science teachers, college students and in particular those

government employees affiliated with the Ministry of Agriculture or the Bahamas Agricultural Industrial Corporation. A sample size of 200 was deemed an adequate cross reference of the sector and surveys were administered in person and over the phone, Due to limitations such as limited contact for many farmers, only 10 professional farmers were surveyed and the vast majority of the survey group came from college students particularly those with science majors. Investigations were carried out between the 25th of February 2013 and the 17th of April, 2013. All persons participating in the survey had to be Bahamian and over the age of 18 years. There was no need to make distinction between the sexes during the course of this study. The surveys also had to be confirmed as not causing harm to those taking the survey. In order to preserve the integrity of the study, the identity of all of the participants remained anonymous thus encouraging participants to respond truthfully. Another hindrance to the distribution of the surveys in the fact that many farmers did not have access or used computers frequently enough for electronic surveys to be a viable option. The choice to include college students in the survey group came from the idea that they should represent an informed audience thus they would serve as a good benchmark for public understanding. These surveys were mainly conducted on or near The College of the Bahamas main Oaks Field campus. The survey questions were specifically chosen for the purpose of not only gaining background information about awareness of nanotechnology but also public opinion on their foods and current levels of crop quality as well as their view on who is responsible for the technological advancement within the agricultural sector. We did this to obtain a context to properly analyse public opinion. A copy of the survey is provided (See appendix 1).

Results and Discussion

The results suggest that there is major dissatisfaction with the current agricultural sector among the respondents with 61% claiming that there needs to be improvement and 28% expressing that it drastically needs improvement. Due to the survey group containing individuals not directly associated with the agricultural sector, these results suggest that there is a widespread underlying lack of faith in the crop quality of Bahamian agriculture even among non experts. Not surprisingly, based on the limited technological progression of the agricultural sector in The Bahamas, there seems to be very limited familiarity with nanotechnology by those persons in the sector. This speaks volumes about the level of training and general cognisance of improvements in the field that would be imperative to see improvement in the field. This ignorance of nanotechnology was seen throughout the survey group with 47% of individuals responding that they have no understanding of nanotechnology and 34% responding that they are unsure as to what nanotechnology is. Even more tellingly, 55% and 29% of respondents claimed to have no understanding and little understanding of the agricultural applications of nanotechnology respectively. These numbers are particularly informative of the limited understanding about nanotechnology throughout the Bahamian public due to the majority of the respondents being persons currently in the agricultural sector or college students. Both of these individual groups are expected to represent a more informed body. This could potentially mean that policy makers wishing to address possible implementation of the use of nanotechnology in The Bahamas would probably have to create educational programs so that the general public could make informed decisions on the issue. The respondents were generally well educated with 49% having a least an associate's degree and 35% in the process of obtaining a college education. One possible explanation for the general lack of understanding about nanotechnology could be due the fact that many of the respondents were relatively

young. Majority of the individuals fell between the 18-20 and 21-29 range accounting for 51% and 27% respectively. 78% of persons taking the survey were female and 21% were male. This imbalance could have been caused by taking surveys on The College of The Bahamas campus. The vast majority of students attending the college are females. Among those survey, 57% of individuals replied that they would be unwilling to take a course on nanotechnology in comparison to 39% who replied that this would. This indicates that many people are unwilling to make substantial effort to gain new knowledge on the topic. This is perhaps because they lack appreciation for potential benefits. We recommend that any educational campaigns that may be launched on the topic be presented in such a way that requires little effort on the part of the target audience in order to receive the information. Based on the results there seems to be a significant portion of people willing to take courses on nanotechnology and avenues for such courses could be for them to be offered at The College of The Bahamas or put on as public workshops by the Ministry of Agriculture. Respondents generally agree that quality of their food is important to them with 86% claiming that it is of high priority to them. Despite the respondents having little understanding of nanotechnology, there was strong support for the implementation of nanotechnology in The Bahamas with 42% responding that they would like to see it in the country. This could be due to the fact that in general people expect and are conditioned generally to believe that technological advancement is not only good but also necessary. Interestingly, 33%, 37% and 27% of persons responded high, medium and low respectively, when asked about the level in which farmers were responsible for technological advancement. This potentially shines some light on the idea that Bahamians generally believe that the change and progress typically comes for a governmental level. This is reflected when the question is posed on the level of responsibility that the government has in ensuring the advancement of new technology. 52% of respondents replied high and 19% replied medium. Another interesting discovery of the survey was that 53% of respondents replied that they would be willing to constantly pay more for organically grown foods while 46% replied that they would not. One explanation the majority of respondents claiming to prefer buying organic food could be that there is stigma against certain types of technologically enhanced foods such as using nanotechnology and genetic modification. Often times these fears are unsubstantiated and are a barrier for those persons seeking to advocate for higher levels of technology in the agricultural sector. After completing the survey, 35% of persons reported that they would seek more knowledge on nanotechnology and 51% said that they may seek further knowledge. With information being at the fingertips of this generation due to search engines such as google or bing, it is not without reason to assume that many individuals will learn about nanotechnology this way as opposed to finding and taking a course on the subject.

Conclusion

The Bahamas' implementation of nanoagriculture can prove to be advantageous to the sector with the proper instillation of polices to regulate this revolutionary technology. The usage of carbon nanotubes and nanocapsules can provide a necessary vehicle for direct transmission of genes, to increase the viability of citrus fruits, crucifers and even livestock. Despite limitations of practicality on large scale usage, Small island Developing states like the Bahamas can benefit from less costly applications like biosensors that can safely monitor and protect imported foods. Based on the results of the survey, it is clear that there needs to be a much larger investigation into the potential ways to optimally incorporate nanotechnology in the country's agriculture sector. There also needs

to be an extensive program to educate the public about the topic and other pertinent topics such as genetically modified foods. In summation, this study has simply provided a starting point for future research on the topic and based on our findings, we feel as if there is a substantial interest in nanotechnologies potential applications.

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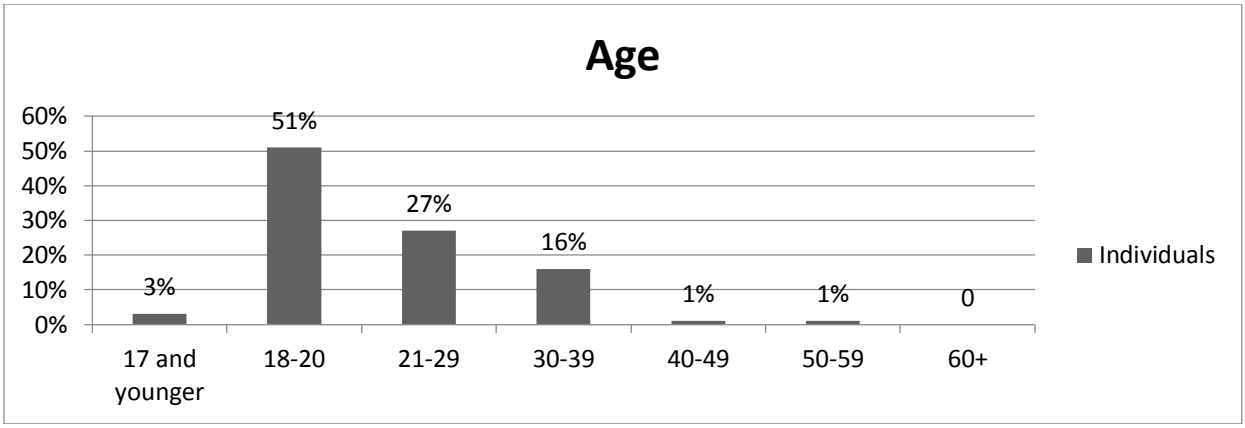

Figure 1: Bar Chart showing the different age groups of the participants involved in the survey

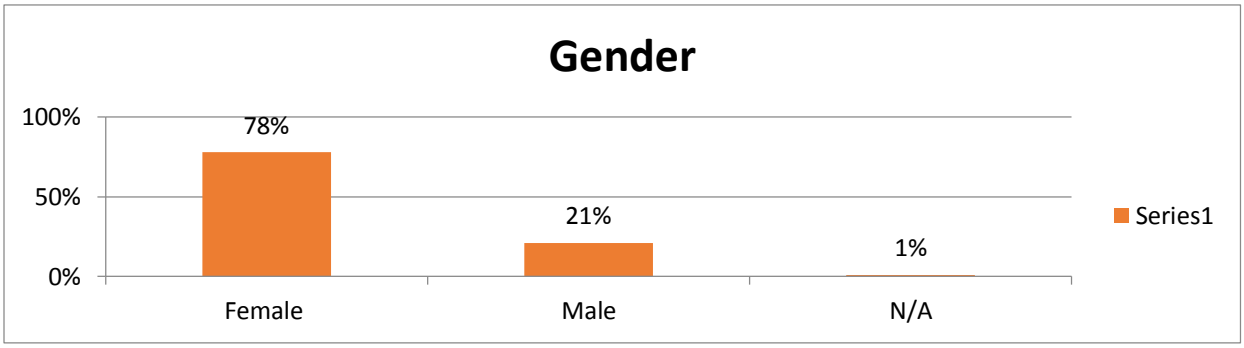

Figure 2: **Bar Chart showing the gender difference between the participants involved in the study**

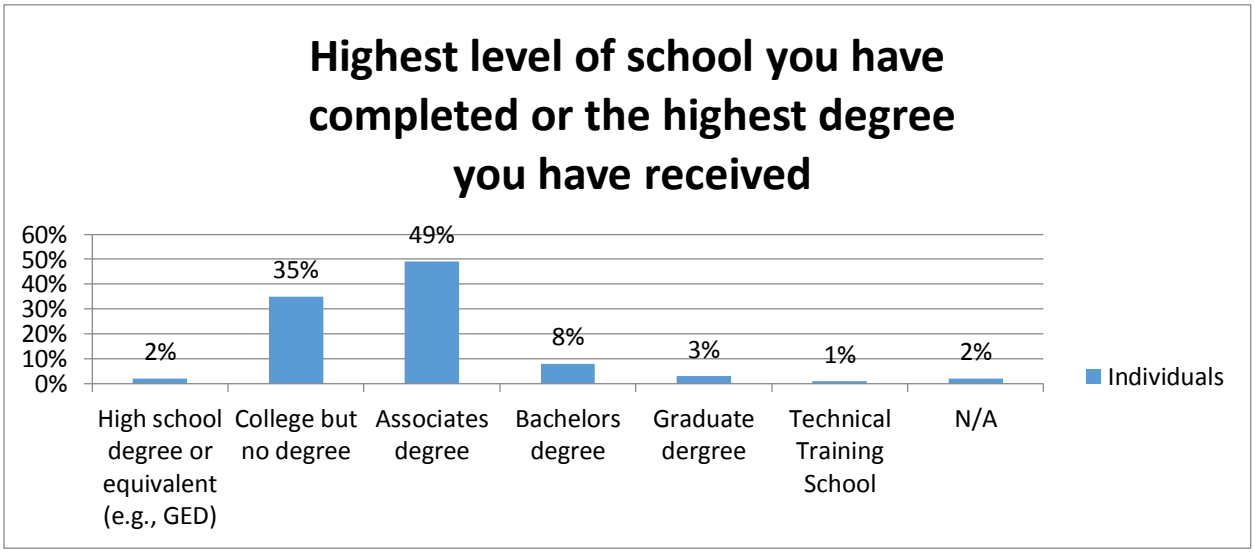

Figure 3: **Bar chart showing the current education level achieved by the participants involved in the study**

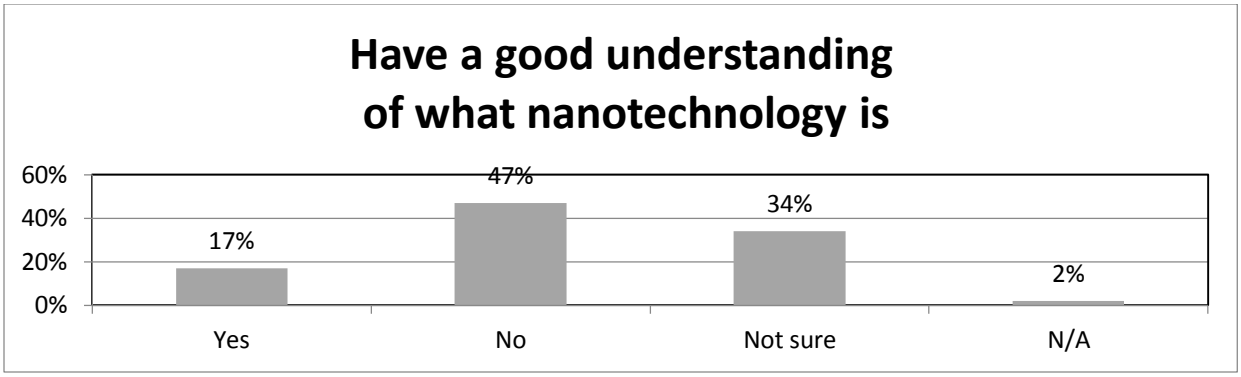

Figure 4: **Bar Chart showing participants' current knowledge of the general idea of what nanotechnology is**

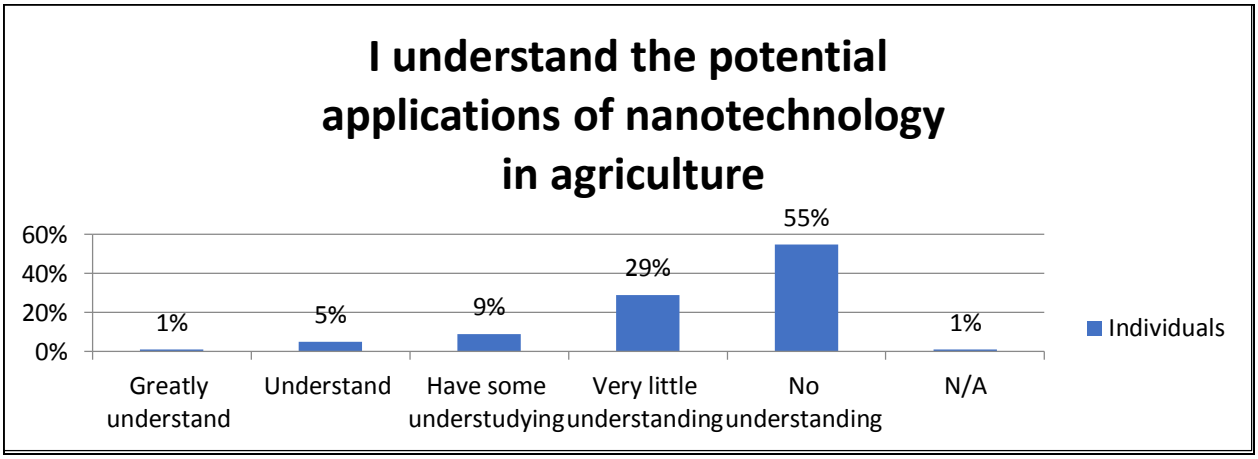

Figure 5: Bar Chart showing participants' current knowledge on the possible usage of Nanotechnology in agriculture

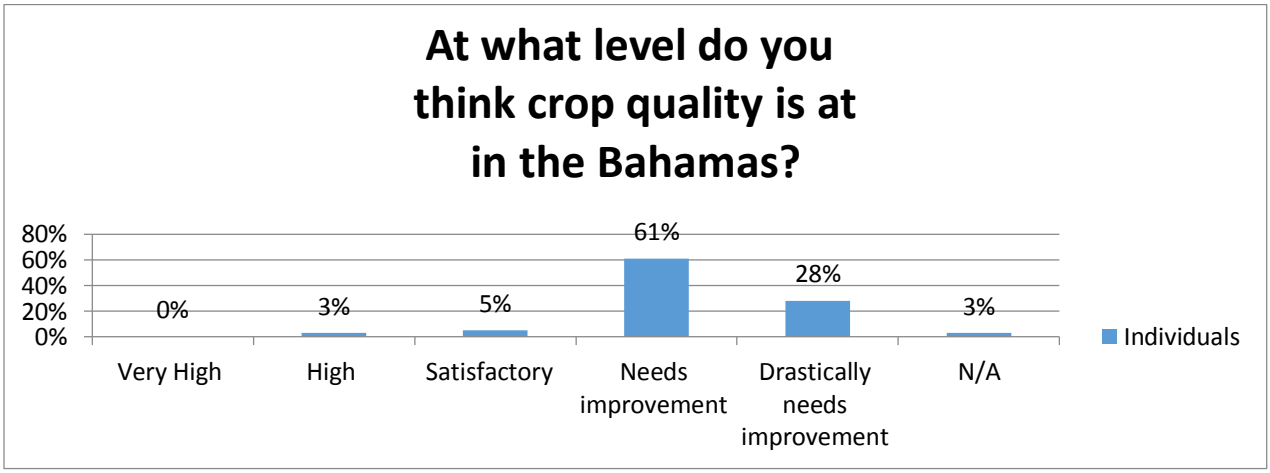

Figure 6: Bar Chart showing participants' opinion toward on the general quality of crops in The Bahamas

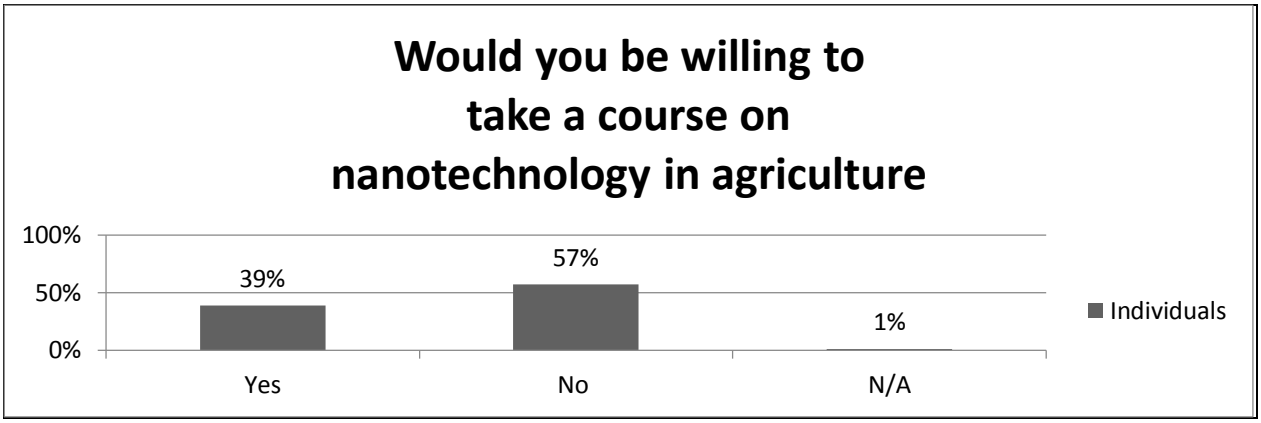

Figure 7: **Bar Chart showing participants' willingness to further their current knowledge on the subject of nanotechnology and its implications in the agricultural sector in The Bahamas**

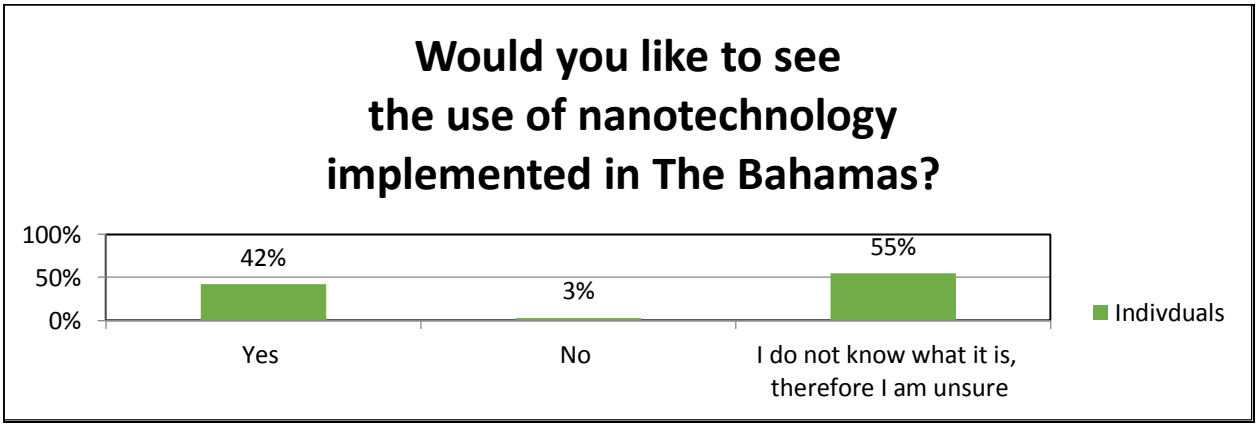

Figure 8: Bar Chart showing participants' opinion toward Nanotechnology being implemented in The Bahamas.

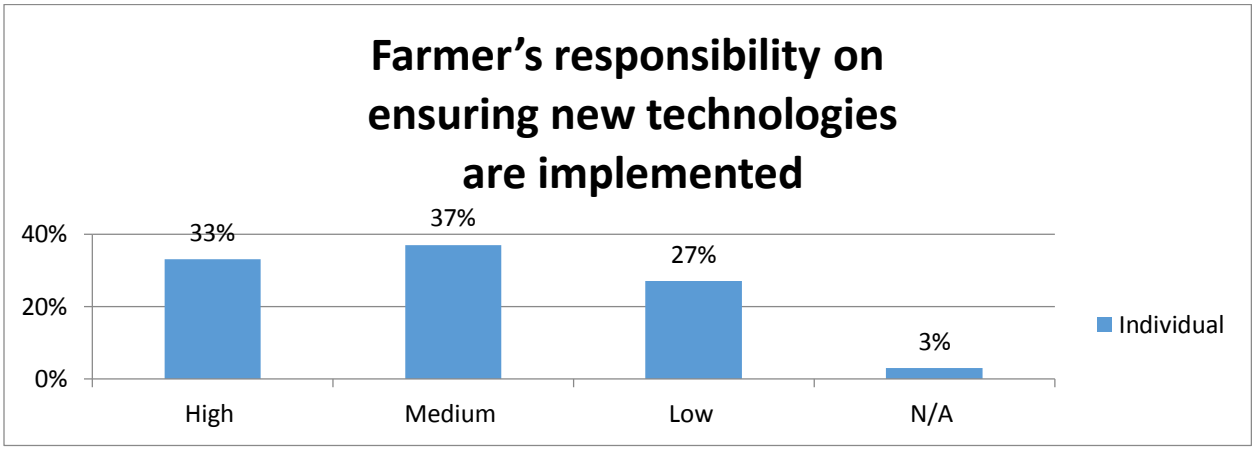

Figure 9: Bar Chart showing participants' opinion toward farmers being responsible for new technologies being implemented in The Bahamas' agricultural sector

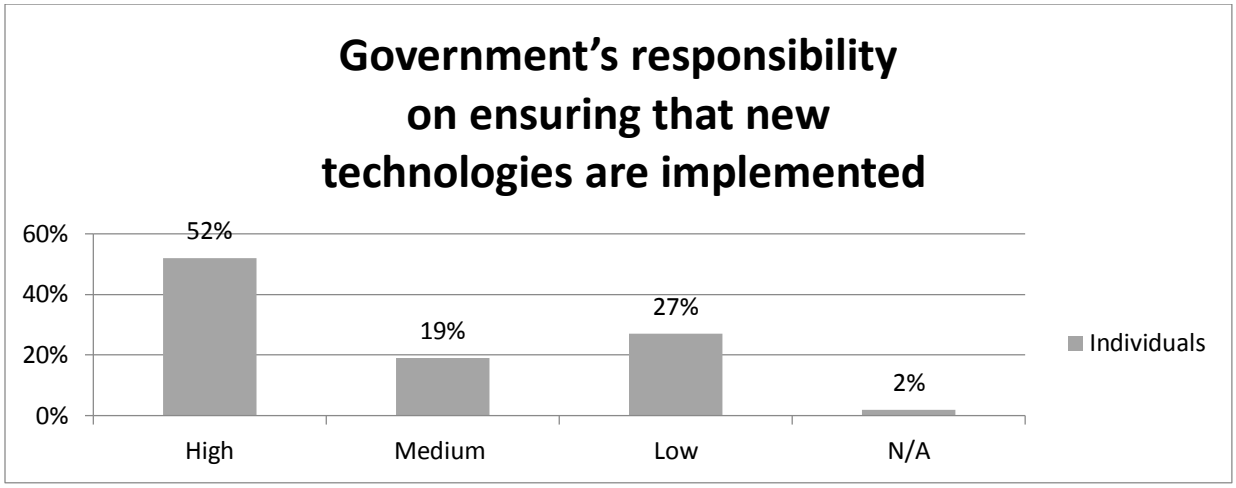

Figure 10: Bar Chart showing participants' opinion toward the Governments' responsibilities in terms of the insurance of new technologies being implemented in The Bahamas

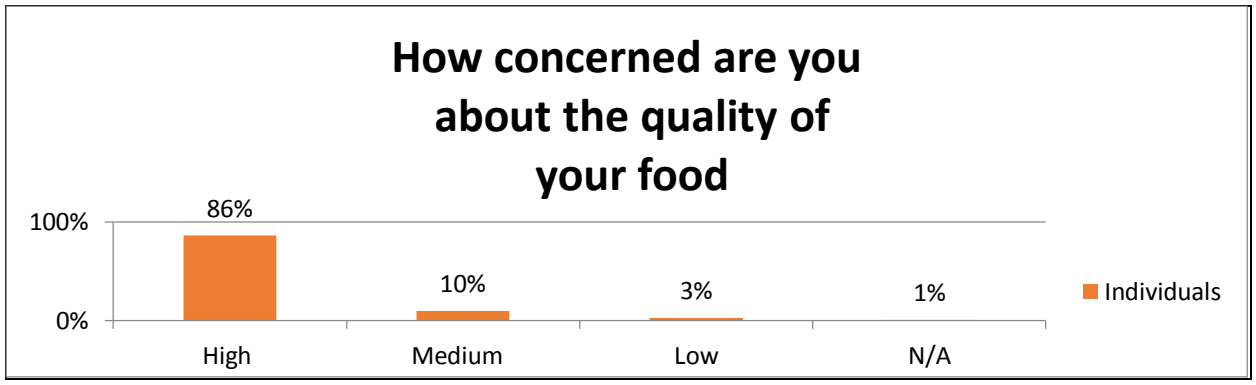

Figure 11: **Bar Chart showing the participants general concern towards their food quality**

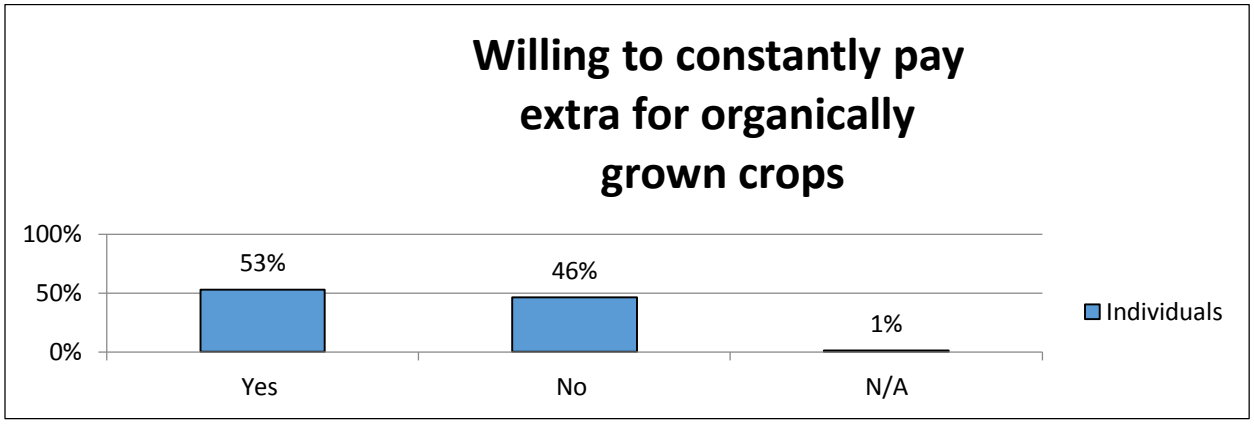

Figure 12: Bar Chart showing consumers' willingness to continually dish out funds for organically grown food

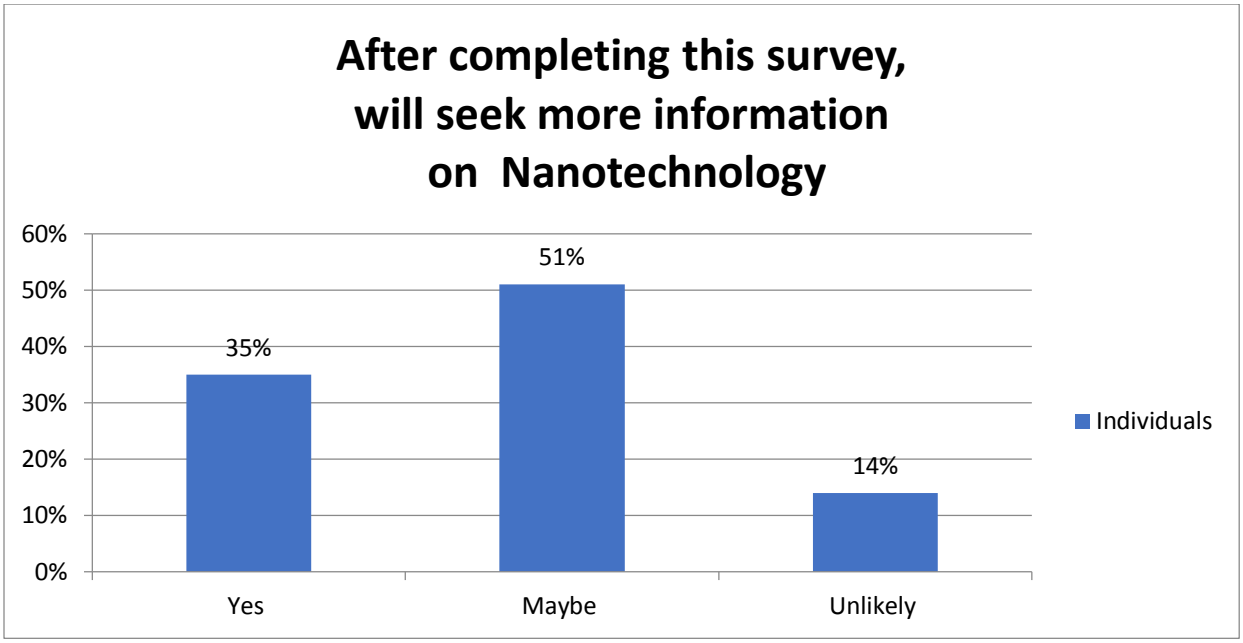

Figure 13: **Bar Chart showing the likelihood of individuals doing follow-up research on the topic presented to them post survey taking.**

Appendix 1

Nanotechnology in Agriculture

1. **Do you consent to participate in this study? (please note if you answer no, you will not be allowed to continue)**

   ○ yes ○ no

2. **Do you live in the Bahamas**

   ○ yes ○ no

   If other please explain

3. **Which category below includes your age?**

   ◉ 17 or younger ○ 18-20 ○ 21-29 ○ 30-39 ○ 40-49 ○ 50-59 ○ 60 or older

4. **What is the highest level of school you have completed or the highest degree you have received?**

   ◉ ○ High school degree or equivalent (e.g., GED)

   ○ Some college but no degree

   ○ Associate degree

   ○ Bachelor degree

   ○ Graduate degree

   technical training (please specify)

5. **What is your gender?**

   ○ Female

   ○ Male

6. **I have a good understanding of what nanotechnology is**

   ○ yes

   ○ no

   ○ not sure

7. **I understand the potential applications of nanotechnology in agriculture**

   ○ greatly understand

   ○ understand

   ○ have some understanding

   ○ very little understanding

   ○ no understanding

8. **At what level do you think crop quality is at in the Bahamas?**

   ○ very high

   ○ high

- needs improvement
- drastically needs improvement

9. Would you be willing to take a course on nanotechnology in agriculture?

- yes
- no

10. Would you like to see the use of nanotechnology implemented in The Bahamas?

- Yes
- No
- I do not know what it is, therefore I am unsure

12. What level of responsibility to would you say that farmers have on ensuring that new technologies are implemented?

High
Medium
Low

13. What level of responsibility to would you say that the government has on ensuring that new technologies are implemented?

High
Medium
Low

14. How concerned are you about the quality of your food? You

High
Medium
Low

15. Are you willing to constantly pay extra for organically grown crops?

Yes
No

16. After completing this survey, will seek more information on Nanotechnology?

Yes
Maybe
Unlikely