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The editorial board is pleased with the publication of the first issue of University of Ha'il-Journal of Science (UOHJS). It is with great hope that this journal will be a valuable tool in its field of specialization. This follows the efforts of the University of Ha'il in promoting scientific research and facilitating all researchers to present their scientific visions and ideas, which in turn is expected to enrich the various knowledge in all scientific fields including: basic Science (Biology, Chemistry, Mathematics, and Physics), Computer Science and Engineering.

The first issue contains articles from various scientific fields including: Biology, Statistics, Mathematics and Mechanical engineering.

I would like to sincerely thank all the researchers who have contributed with their scientific productions, and also to the journal's editorial board for their efforts in issuing this volume, and to the University Administration for its support of the journal. I pray to Allah that this journal will be a significant addition to the field of scientific researches.

Allah bless ...

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ROTHSCHILD, M., VON EUW, J., REICHSTEIN, D., SMITH, D. & PIERRE, J. (1975) Cardenolide Storage in *Danaus chrysippus* (L.) with Additional Notes on *D. plexippus* (L.). Proc. R. Soc. Lond. B Biol. Sci. 190, 1-31.

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Content Pages

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Effect of Sublethal Dose of the Viper *Cerastes Cerastes* Crude Venom on Rabbit Biochemistry and Hematology

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ABSTRACT

The objective of this study was to explore the impact of sublethal concentrations of viper *Cerastes cerastes* crude venom on biochemical and hematological parameters in rabbit. Thirty adult male rabbits were divided into three groups (10 individuals per each group). The first group was the control which received physiological saline. The second group was injected interaperitoneally with 0.3µgm/g crude venom and the third group was injected with 0.6 µgm/g crude venom. The results indicated that 0.3 µgm/g crude venom induced significant decreases in total protein, globulin, triglycerides and cholesterol, and significant increases in serum glucose and liver enzymes (ALT and AST). The above mentioned parameters showed highly significant changes when 0.6 µgm/g crude venom was used. Haemoglobin concentration (Hb), red blood cell count (RBCs), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC) were significantly decreased. Inversely, hematocrit (PCV%), mean corpuscular volume (MCV) and white blood cell count (WBCs) were significantly decreased. In conclusion, sublethal concentrations of viper *Cerastes cerastes* crude venom induced changes on biochemical and haematological parameters of rabbit in a way that could induces animal health disorders.

Keywords: *Cerastes*; venom; rabbit; hematology; biochemistry.

1. INTRODUCTION

Cerastes cerastes and *C. c. gasperettii* (family Viperidae) are more familiar horned vipers of the great deserts of North Africa and the Middle East (Gasperetti, 1988). There are approximately 420 venomous species of snakes living on the earth (Lewis and Gutmann, 2004). Snakes are considered to be exceptional model organisms (Shine and Bonnet, 2000), in part because of their unique adaptations for feeding and foraging (Greene, 1997). Limited ecological studies have been done on snakes and lizards of different geographical regions of Saudi Arabia like Southern Hijaz (Parker, 1938), Eastern Arabia, Northeastern Arabia (Mandeville, 1967) and Central Arabia (Al-Wailly and Al-Uthman, 1971). The viper distributes on a large scale in Africa (Marsh ***et al***., 1997). A poisonous viper, as the name suggests, lives in the sandy deserts of Egypt (Zimmerman ***et al***., 1981). Many studies have been conducted on the metabolism, cardiovascular and hematological effects of snake venom on humans and animals (Abu-Sinna ***et al***., 1993). *C. cerastes* venom is toxic, primarily due to the activity of various proteins and enzymes that it contains (Oukkache ***et al***., 2012). The venom also displays a range of biological activities including anti-angiogenic, antimicrobial, antibacterial, and antagonist effects (Hanane-Fadila and Fatima, 2014).

The significance of the biochemical blood parameters for the objective assessment of health disorders and monitoring stress factors in pre-clinical stages is necessary (Hinton ***et al***., 1982). Such biochemical and

physiological values can be used as indicators of care in breeding rabbits (Hoy and Verga, 2006). These parameters are also important and reliable to monitor health and nutrition in animals (Gupta ***et al***., 2007). Blood composition may be affected by some factors such as nutrition, management, growth, sex and age diseases (Ewuola ***et al***., 2004). The study is designed to investigate the effects of two doses of the *C. cerastes* crude venom on the serum biochemical and hematological parameters of rabbits.

2. MATERIALS AND METHODS

2.1 Collection of snake venom

Horned viper *C. cerastes* (n = 10), were donated from private pet shop in Cairo of Egypt. The viper individuals were identified and the venom was collected by manual milking and then all the individuals were returned to pet shop. Venoms were taken to the clinical laboratory in the national Research Center of Egypt in which all experimental procedures have been conducted. Venom was freeze-dried and stored at -20 °C until use. LD_{50} with a dose of 0.66 µg/g of crude venom was used according to Meier and Theakston (Meier and Theakston, 1986).

2.2 Experimental design

Thirty male rabbits were used with an average body weight of 801 ± 28g. Healthy rabbits were selected from the animal house at the Faculty of Agriculture, University of Cairo. These rabbits were placed in the measuring 45 × 30 × 42 cm rods in a standard case and are provided daily with the experimental diets in the form of mash. *Ad libitium* and clean drinking water was provided throughout the experimental period. The animals were adapted under room temperature and humidity with normal light / dark cycle for two weeks and had free access to water and a standard pure powder diet.

Animals were divided into three groups. The first group (control, n=10) was injected interaperitoneally (i.p.) with 100 µL physiological saline (0.9 % NaCl). The second group (n=10) had received a single 0.3µgm/g body weight dose of crude venom in 100 µL saline solution interaperitoneally. The third group (n=10) had received a single 0.6 µgm/g body weight dose of crude venom in 100 µL saline solution interaperitoneally. After 24 hours of the injection, blood samples were randomly collected intravenously from rabbit ear vein using a disposable needle and syringe. Each blood sample was divided into two tubes; the first tube contained a potassium dioxide salt of acetylene diphenyl acetate acid (EDTA-K2) as an anticoagulant for hematology. The second tube was without an anticoagulant for biochemistry tests. Biochemical tests were conducted in the National Research Center in Cairo, Egypt.

Sera were separated by centrifuging the blood samples at 3000 g for 30 min. Kits for the biochemical parameters were purchased from Spinreact, S. A. Ctra. Santa Coloma, Spain. Glucose was measured as described by the method of Trinder (1969). Total serum protein was determined according to Peters (1968). Serum albumin was determined according to Doumas ***et al***. (1972). Globulin was measured as the difference between total protein and albumin. Cholesterol (Young ***et al***., 1972), triglycerides (Hare, 1950), creatinine (Patton and Crouch, 1977), urea (Fossati, et al., 1980), uric acid (Reitman and Frankel, 1957) were determined according to kit guidelines. Alanine transaminase (ALT) and aspartate transaminase (AST) activities were also measured (EL-Asmar ***et al***., 1979). Alikaline phosphatase (ALP) was measured according to El-Aaser and El-Merzabani (1975).

The haematological parameters were analyzed through standard procedures. WBCs and RBCs counts have been obtained by the haemmocytometern method, while the differential counting was performed according to Schalm ***et al***. (1975). The packed cell volume (PCV) was determined by the microhymatocrit method (Steel and Torrie, 1980). Hemoglobin (Hb), mean hemoglobin (Mesh), average particle size (mKV) and mean surgical hemoglobin concentration were obtained measured and calculated according to Thrall and Weiser (2002). Mean corpuscular haemoglobin (MCH), mean corpuscular volume (MCV) and mean corpuscular haemoglobin concentration (MCHC) had been obtained from the calculation according to the standard equations.

2.3 Statistical Analysis

Data have been statistically analyzed by Analysis of Variance (ANOVA) (Al-Jammaz ***et al***., 1999). Means were compared using Duncan multiple range test. Percentage changes were calculated as follow: % decrease = decrease ÷ original number × 100, % increase= increase ÷ original number × 100 (https://www.skillsyouneed.com/num/percent-change.html).

3. RESULTS

Significant reduction in total protein, globulin ($p<0.05$) , cholesterol and triglycerides ($p<0.01$) have been recorded in male rabbits after 24 hours injection with a single dose of 0.3µgm/g bw crude venom compared to the control (Table 1). These decreases showed percentage change of -20.53%, -29.90%, -31.2% and -35%, respectively. Meanwhile, injection of a single dose 6 µgm/g bw of crude venom for 24 hours induced highly significant decreases in the abovementioned parameters. The percentages of reduction change were -28.46%,-33.55%, -38.5 % and -47 %, respectively (Table 1). On the other hand, 0.3 µgm/g bw crude venom led to increases ($p <0.01$) in creatinine, urea and glucose at 0.3 µgm/g bw and this increase was highly significant ($p <0.001$) when 0.6 µgm/g bw was used as compared to the control rabbits. This elevation exhibited % changes of 87.8%, 95.3% and 60%, respectively for the high dose (Table 1).

The data (Table 2) showed that significant increase in ALT ($p< 0.01$), AST, ALP ($p< 0.05$) and ACP ($p< 0.01$) at the single dose of 0.3 µgm/g bw crude venom for 24 hours and highly significant ($p <0.001$) elevations in these enzymes were shown when 0.6 µgm/g bw crude venom were used as compared to those of the control rabbits. These increases exhibited 81%, 34.4%, 44.51% and 73.3% percentage changes, respectively.

The present results (Table 3) showed that RBCs count, Hb concentration, MCH and MCHC were significantly decreased ($p<0.05$) at 0.3 µgm/g bw crude venom while more significant reduction in these parameters at 0.6 µgm/g bw crude venom were shown as compared to those of the control animals. These reductions showed - 38.5%, - 30%, - 19%, and - 44.3% percentage changes, respectively. On the other hand, the data had shown significant increases ($p<0.05$; $p<0.01$) in WBCs, PCV% and MCV at 0.3 µgm/g bw single dose. This elevation was highly significant ($p<0.01$; $p<0.001$) at 0.6 µgm/g bw as compared to those of the controls. The % changes of these increases were 47.1%, 32.4% and 74.6%, respectively.

4. DISCUSSION

The present data showed reduction in total protein and globulin in rabbits after injection with two doses of crude venom for 24 hours and these results were supported by the renal function disorders and bleeding in some internal organs. The elevation in vascular permeability and bleeding in vital organs is due to toxic effect of different snake toxins as discussed by Meyer and Stoke (1991) and March ***et al***. (1997). Moreover, the snake bites cause a toxic impact on the victims due to the presence of lipolytic and proteolytic enzymes in their toxins. It is worthy to mention that several studies have been conducted on the metabolic and hematological effects of snake venom on humans and experimental animals (Tan and Ponnudurai, 1990; Al-Jammaz ***et al***., 1999) and found that various snake venoms cause alterations in rat metabolism (Tan and Ponnudurai, 1990).

In this study, high levels of urea and creatinine in the serum of rabbits indicated the weakness in the kidney function. Similar observations had been reported in mice treated with various venoms (Soslau ***et al***., 1988).

Table 1. The impact of two doses of viper *Cerastes cerastes* on some biochemical parameters in Rabbits after crude venom injection for 24 hours (mg/dl).

	Control	(0.3µgm/g)		(0. 6µgm/g)	
	Means ± S.E.	Means± S.E.	Change%	Means ± S.E	Change%
Total protein	6.43±0.42	5.11±0.34*	- 20.53%	4.6±0.34*	- 28.46%
Albumin	3.41±0.24	3.00±0.21	- 12.02%	2.6±0.22*	- 23.75%
Globulin	3.01±0.121	2.11±0.111*	- 29.90%	2.2±0.23**	- 33.55%
Creatinine	0.49 ±0. 12	0.72 ±0.11**	46.9%**	0.92 ±0.13***	87.8%
Urea	38.6 ± 1.8	61.44 ± 2.4**	59.2%	75.4 ± 3.3***	95.3$
Uric acid	2.5± 0.13	1.8 ± 0.21	- 28%	1.1± 0.16	- 56%
Glucose	85.3±3.12	112.3±3.5**	31.7 %	136.4±2.5***	60%
Cholesterol	92.2±4.21	63.4±1.2**	-31.2%	56.7±8.13**	- 38.5%
Triglycerides	85.6±2.4	55.6±3.3**	-35 %	45.34±3.3**	- 47 %

* p<0.05, ** p<0.01, *** p<0.001.

Table 2. The impact of two doses of viper *Cerastes cerastes* on liver function, enzyme in rabbits after crude venom injection for 24 hours (u/l).

Parameter	Control	(0.3µgm/g)		(0. 6µgm/g)	
	Means ± S.E.	Means ± S.E.	Change%	Means ± S.E.	Change%
ALT	79.8±3.6	112.5±7.21**	40%	144.5±3.7***	81%
AST	125.41±6.6	153.87±8.70*	22.7%	168.5±6.4**	34.4%
ALP	188.5±7.14	233.4±2.4*	23.8%	272.4±2.6**	44. 51 %
ACP	122.4±1.3	182.3±3.2**	49%	212.1±1.6***	73. 3 %

Table 3. The impact of two doses of viper *Cerastes cerastes* on haematological parameters in rabbits after crude venom injection for 24 hours.

Parameters	Control	(0.3µgm/g)		(0. 6µgm/g)	
	Means ± S.E.	Means ± S.E.	Change%	Means ± S.E.	Change%
RBCs x 10^6/*u*l	5.2 ± 0.26	4.2+ 0.26*	- 19.2%	3.2+0.26**	- 38.5%
WBCs x 10^3/*u*l	5.1+ 0.42	6.4+ 0.21*	25.1%	7.5+0.45**	47.1%
PCV%	31.2 ± 0.27	37.2 ± 0.48*	19.2%	41.3±0.72**	32.4%
Hb g/dl	13.8 ± 0.61	11.6 ±0.58*	- 16%	9.7 ±0.72**	- 30%
MCH pg/cell	28.7 ± 1.13	25.0 ± 1.12	- 13%	23.2 ± 1.6*	- 19%
MCV	70.12 ± 3.13	91.2 ± 1.18**	30%	122.4±1.3***	74.6%
MCHC g/dl	43.6 ± 1.13	31.2 ± 1.2*	- 28.4%	24.3 ± 1.2**	- 44.3%

Venoms increase blood vessel permeability, along with renal damage which exacerbates the lack of blood proteins and hyponatremia. Moreover, the elevation of urea and creatinine associated with the reducing of uric acid, in the current study, supports the proposed weakness of kidney function. Similar results were reported for rats subjected to various viper venoms (Rahmy ***et al***., 1995). In the current study, viper venom caused an elevation in blood glucose level as venoms produce hyperglyceamia in rats and mice (Sant and Purandare, 1972). It can be attributed that increases in blood glucose level affects the metabolism of glycogen in the liver cells, muscle fibers and medullary catecholamines which stimulate the dissolution of glycogen and gluconeogenesis in those tissues (Mohamed ***et al***., 1981). The present work had indicated reduces in cholesterol and triglyceride. These results are consistent with other investigators who indicated decline in these parameters in the blood of laboratory animals injected with snake venom. They suggested that the snake venom may mobilize lipid level from adipose and other tissues (Ohhira ***et al***., 1991).

In this study liver cells could be exposed to damage by the viper venom which makes liver accumulates fatty acids, thus becoming fatty liver and altering cell membranes and tissue permeability for electrolytes (Al-Jammaz, 2002). Such electrolyte disturbances have been reported in serum of rats after injection by various snakes' venom. Furthermore, Meier and Stocker (Al-Jammaz ***et al***., 1999) indicated that, these disorders may be due to acute nephropathy following snake bites. El-Asmar ***et al***. (1979) predicted that this effect was induced by the stimulation of adrenal cortex leading to the secretion of aldosterone. The present elevation in ALT, AST, ALP and ACP activity indicated that viper venom caused damage of liver, heart and other organs. Such findings are in agreement with previous reports on venoms of other snake species (Sant and Purandre, 1972; Mohamed ***et al***., 1980). It can be concluded that sublethal concentrations of viper *C. cerastes* crude venom caused changes on biochemical and haematological parameters of rabbit.

The reduction in RBCs count may be due to macrocytic or normocytic anemia (Al-jammaz ***et al***., 1992) and also due to a common effect of toxicity with various types of pollutants (Tuschiya, 1979). It was found that snake venom causes dissolution of the blood and the division of red blood cells, which represent a potential source of magnification error in RBCs count due to the presence of hemolytic factors found in snake venom such as Vsvoulibaz- A2 and phospholipase (Borgeest ***et al***., 2004). Jiang ***et al***. (1988) showed the blood dissolution by snake venom depends on the age of RBC and blood viscosity. These results agreed with those obtained by Berberian and Enan (1989) who studied the effects of some antimoulting compounds on the haematological picture in male rats and found significant reductions in Hb, RBCs, MCH and MCHC.

Other investigators related RBCs changes to calcium concentration and pH level as the increase in the pH causes a significant increase in blood dissolution (Bultron ***et al***., 1993). WBCs count was significantly increased in rabbit injected with two doses of crude venom for 24 hours and the hematocrit PCV% increased too. These findings agreed with those obtained by Guilhermino ***et al***. (1998) which indicated that when rats were exposed to cadmium the number of WBCs was elevated. The increase in the haematocrit values may be due to the reduction in RBCs and their swelling as evidenced by the significant increase in MCV.

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Nutritional Value and Phytochemical Constituents of some Plantago spp. of Ha'il Region, Saudi Arabia

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ABSTRACT

The Plantago genus dominates landscapes across the world and comprises about 256 species, which plays an important role as forage for grazing animals and pharmaceutical purposes. The current study was carried out to evaluate the nutritional value and phytochemical contents of four local plantago species (*Plantago ciliata, Plantago lanceolata, Plantago ovata* and *Plantago cylindrica*), which were collected from different natural parts of Ha'il region, which lies in the middle-north of Saudi Arabia. The results revealed that the values obtained (based on dry weight; DW) of moisture, ash, crude protein, crude fat, crude fiber, and carbohydrates contents were varied from 29.0 to 52.3%, 7.0 to 16.0%, 10.7 to 14.6%, 0.6 to 1.6%), 11.2 to 23.1%, and 11.6 to 24.0%, respectively. The values recorded for acid detergent fiber (ADF %) and total digestible nutrient (TDN %) were 14.0 to 74.0%, 26.0 to 86.0%, respectively. In addition, the values of calcium and phosphorous contents were varied from 0.2 to 0.3 and 0.1 to 0.2 mg kg–1 DW, respectively.

Phytochemical analysis of the aqueous solution of the Plantago species showed the presence of varying amounts of protein-xanthoprotein, tannins, cardiac glycosides, flavonoids, saponins, terpenoid, phenols, glycosides and saponins. However, alkaloids were absent only in *Plantago cylindrica,* while cardiac glycosides were absent only in *Plantago lanceolata.* On the other hand, flavonoids were observed only in *Plantago ovata,* while resins were not observed in all species.

Keywords: Nutritional value; Phytochemical content; *Plantago* spp; Forage; Ha'il.

1. INTRODUCTION

Rangelands of Ha'il region at the middle-north of the Kingdom of Saudi Arabia have been severely deteriorated due to the combined effects of animal pressure, human disturbances and predominant aridity (Alghamdi, 2017). Overgrazing, however, was considered the most influencing factor due to the population increase and the demand of red meat and dairy prooducts (Mseddi ***et al.***, 2016). Providing enough feed resources for grazing animals in such harsh and arid regions, has led to the development of animal farming systems that integrate the use of foliage with local plant species to produce considerable amounts of high protein biomass and energy (Devendra, 1990). Therefore, laboratory analyses are needed to determine the nutritive value and phytochemical content of local promising forage species which have been well documented in the flora of Ha'il such as members of the family Plantagonaceae (Alghamdi ***et al.,*** 2018).

Plantago is a genus comprising about 256 species worldwide and belongs to the Plantaginaceae family. It plays an important role in grazing animal feed, pharmaceutical, medical, healthcare and industrial purposes

(Esmaeili ***et al.,*** 2014). Plantago species grow in various types of habitats, including; deserts, sea cliffs, woodlands, disturbed areas and tropical mountains. Plantago genus varies greatly in distribution across the world with many species restricted to specific areas while others are more widespread. Also, species of this genus are found to vary from only spring to summer plants as well as from biennials to perennials (Primack, 1976).

There is an increasing attention in the Plantago phytochemicals, due to their potential applications in functional food products and medicines. Plantago species have numerous phytochemicals in their different organs (e.g., leaves, seeds, and roots). These phytochemicals apparently have medicinal properties and can be used also as taxonomic markers (Samuelsen, 2000). These compounds improve the physiological condition of the grazing animals and reduce the need of antibiotic growth promoters; as well they are good source of protein and minerals (Sano ***et al.,*** 2002). Therefore, the bioactive compounds with the nutrients contained in the Plantago species encourage the use of them as a supplementary diet for the improving of health and production of grazing animals as suggested by Sumon ***et al***. (2014). For this purpose, the current study was carried out to evaluate the nutritional value and phytochemical contents of four local species of the genus Plantago that have been collected from different natural parts of Ha'il region. The four Plantago species submitted to perform the purpose of this study were *Plantago ciliata, Plantago lanceolata, Plantago ovata* and *Plantago cylindrica*.

2. MATERIALS AND METHODS

2.1 Study Area

The Plantago species in the current study were collected from Ha'il region, that lies in the middle-north of the Kingdom of Saudi Arabia between 25° 29′N and 38° 42′E and it extends over an area of 118,322 km^2. The mean temperature in Ha'il ranges from 10.8°C at Winter to 34.1°C at Summer and the annual rainfall is about 104.4 mm which falls mostly in Winter (El-Ghanim *et al.,* 2010).Therefore, rangeland in Ha'il is classified among the arid-zones with short scattered rainy season and prolonged dry period that lasts most of the year.

2.2 Sample collection

Four Plantago species (*Plantago cilata, Plantago lanceolata, Plantago ovata* and *Plantago cylindrica*) were collected in the 2016 spring season from local natural rangelands of Ha'il region, Saudi Arabia, as shown in Table 1. Fresh grass specimens were uprooted by digging the soil and preserved in polyethylene bags. The samples were then transferred to the laboratory of Department of Biology, Faculty of Science, University, of Ha'il for identification and further analysis. Samples were dried in a vacuum oven at a temperature of 105°C for 24h, and 50 grams of each dried sample were then packed in paper sacks and stored for further analysis.

Table 1: Plant species from natural rangeland of Ha'il, Kingdom of Saudi Arabia, collected in 2016 spring season.

No.	Name	Location	Coordinates
1	*Plantago ciliata*	Al-Qaed dist. Ha'il	$27^0 44' 25''$ N $41^0 36' 23''$ E
2	*Plantago lanceolata*	Al-Qaed dist. Ha'il	$27^0 51' 8''$ N $41^0 43' 32''$ E
3	*Plantago ovata*	Salma mountain Ha'il	$27^0 05' 30''$ N $4207' 54''$ E
4	*Plantago cylindrica*	Al-Qaed dist. Ha'il	$27^0 44' 25''$ N $41^0 36' 23''$ E

2.3 Biochemical analysis

The protocol of AOAC, (1984) was applied assess the proximate chemical components of the tested samples. Chemical components assessed include; moisture, ash, crude protein (The total protein in the sample including true protein and non-protein nitrogen), crude fat (Ether extract) (fat is the energy dense nutrient which contains 2.25X to 2.8X the energy found in carbohydrates), crud fiber (the residue of plant materials remained after solvent extraction followed by digestion with dilute acid and alkali), carbohydrates content, Ca and P (mg kg–1 dry weight; DW) content. Acid Detergent Fiber (ADF) and Total Digestible Nutrient (TDN) were calculated based on the protocol of AOAC, (1973). Reported results were expressed as percentage (%) of dry weight (DW).

2.4 Phytochemical analyses

Phytochemical analyses include determination of protein, -xanthoprotein, alkaloids, saponins, tannins, cardiac glycosides, terpenoid, flavonoids, phenols, glycosides and resins in the aqueous solution of the samples were performed based on methods of analyses described by AOAC (1990).

2.5 Statistical Analysis

Results were reported as the average of three independent measurements and were analyzed statistically with SPSS-17 statistical software (SPSS Inc., Chicago, IL, USA).

3. RESULTS

Nutritional value estimation of the Plantago samples of the current study was evaluated following proximate analysis protocol as it plays an important role in assessing the suitability of plant species for different grazing animals' requirements (Khan, et al 2014).

3.1 Moisture content

Figure (1) shows that the percentage of moisture content of the tested species was ranged significantly from the highest value found in *Plantago cylindrica* (52.29%,DW) to the lowest in the rest of the samples (37.19%,DW), (34%, DW), (29%,DW) in *Plantago ovata*, *Plantago ciliata* and *Plantago lanceolata,* respectively.

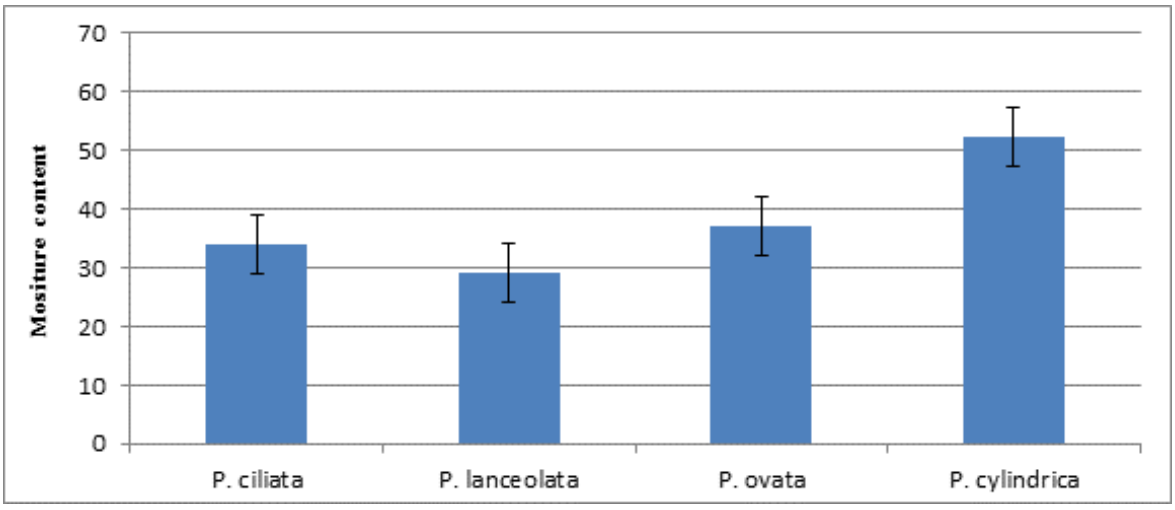

Fig. 1: Percentage of moisture content of some Plantago species of Ha'il /Saudi Arabia. Data are expressed as mean ± SE of replicate determinations (*n*=3).

3.2 Ash content

As shown in Figure (2) the percentage of moisture content of the species was ranged significantly from the low in *Plantago cylindrica* (7.0%,DW) to the high value in the rest of the samples (16.0%,DW), (15.0%,DW), (12.0%,DW) in *Plantago ovata*, *Plantago lanceolata* and *Plantago ciliata,* respectively.

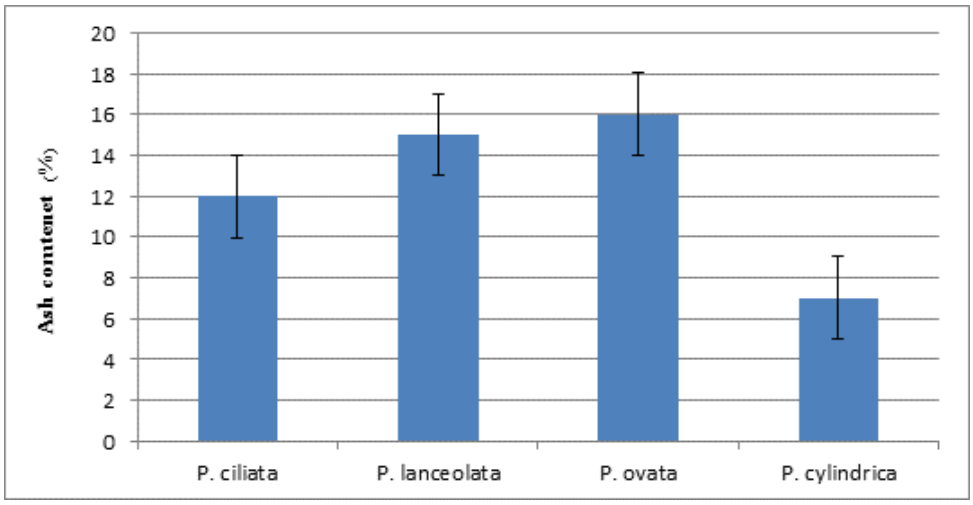

Fig. 2: Percentage of ash content of some Plantago species of Ha'il /Saudi Arabia. Data are expressed as mean ± SE of replicate determinations (*n*=3).

3.3 Crude protein content

Figure (3) shows the crude protein content of the species was ranged significantly from the lowest in *Plantago ovata* (10.68%,DW) to the highest value in the rest of the samples (14.63%,DW), (14.62 DW %), (14.56%,DW) in *Plantago lanceolata*, *Plantago cylindrica* and *Plantago ciliata,* respectively.

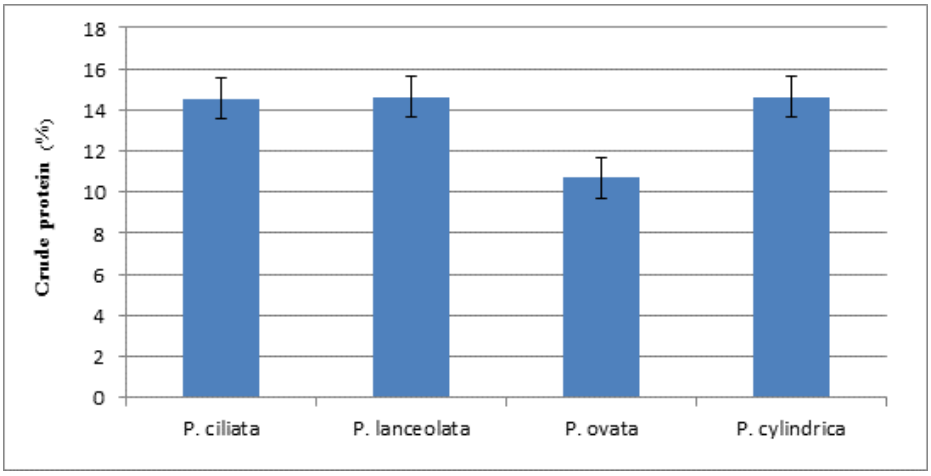

Fig. 3: Percentage of crude protein content of some Plantago species of Ha'il/Saudi Arabia. Data are expressed as mean ± SE of replicate determinations (*n*=3).

3.4 Crude fat content

Figure (4) shows the crude fat content of the species was ranged significantly from the highest in *Plantago cylindrica* (1.6%,DW) and *Plantago lanceolata* (1.3%,DW) respectively to the lowest value in the rest of the samples (37.19 DW %), (34 DW %), (29 DW %) in *Plantago ovata* (0.7%,DW) and *Plantago ciliata* (0.6%,DW), respectively.

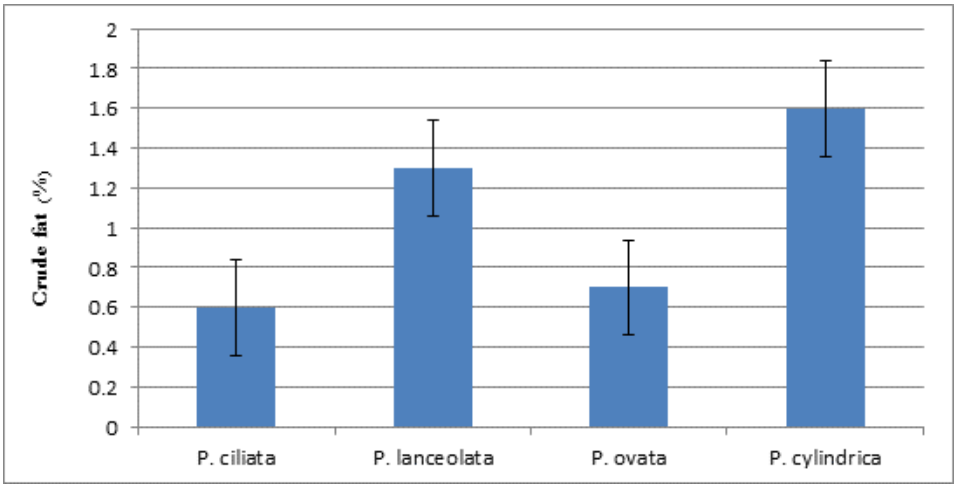

Fig. 4: Percentage of crude fat content of some Plantago species of Ha'il /Saudi Arabia. Data are expressed as mean ± SE of replicate determinations (*n*=3).

3.5 Crude fiber content

Figure (5) shows that the percentage of crude fiber content of the species was ranged significantly from the highest in *Plantago ciliata* (23.12 %,DW) to the lowest value in the rest of the samples (16.0 %,DW), (12.0%,DW), (11.2 DW %) in *Plantago ovata*, *Plantago lanceolata* and *Plantago cylindrica,* respectively.

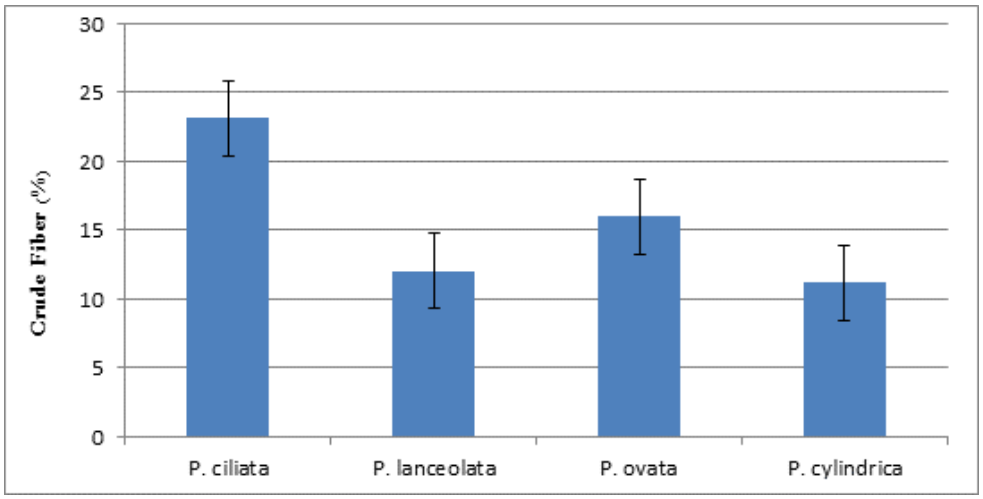

Fig. 5: Percentage of crude fiber content of some Plantago species of Ha'il /Saudi Arabia. Data are expressed as mean ± SE of replicate determinations (*n*=3).

3.6 Carbohydrates content

Figure (6) shows an insignificant increase in carbohydrates content among the species which was ranged from 11.64 DW % in *Plantago lanceolata* to 24 DW % in *Plantago cylindrica.*

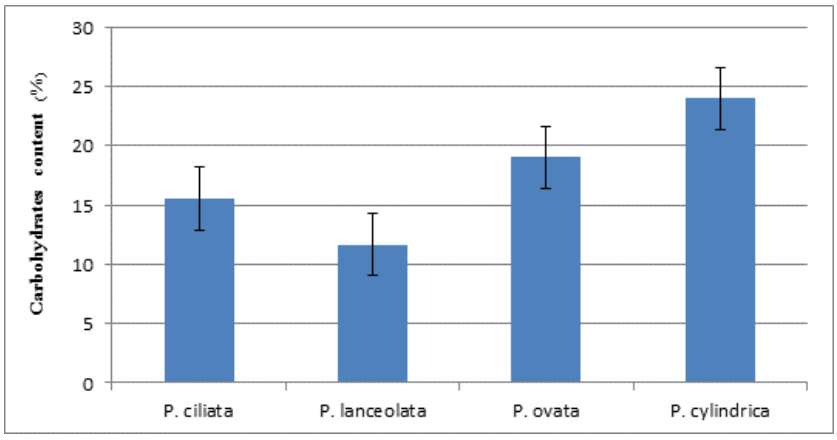

Fig. 6: Percentage of carbohydrates content of some Plantago species of Ha'il /Saudi Arabia. Data are expressed as mean ± SE of replicate determinations (*n*=3).

3.7 Calcium and phosphorus content

Figure (7) shows that the calcium content of the species was ranged significantly from the lowest in *Plantago lanceolata* (0.2 mg kg^{-1}) to the highest value in the rest of the samples (0.32 mg kg^{-1}), (0.3 mg kg^{-1}), (0.3 mg/kg^{-1}) in *Plantago cylindrica*, *Plantago ovata* and *Plantago ciliata* , respectively. In addition, phosphorous content was ranged significantly from the highest value (0.17 mg/kg) in *Plantago cylindrica* to the lowest values in the rest of the species (0.13 mg/kg) (0.12 mg/kg), (0.11 mg/kg) in *Plantago ovata, Plantago ciliata* and *Plantago lanceolata,* respectively.

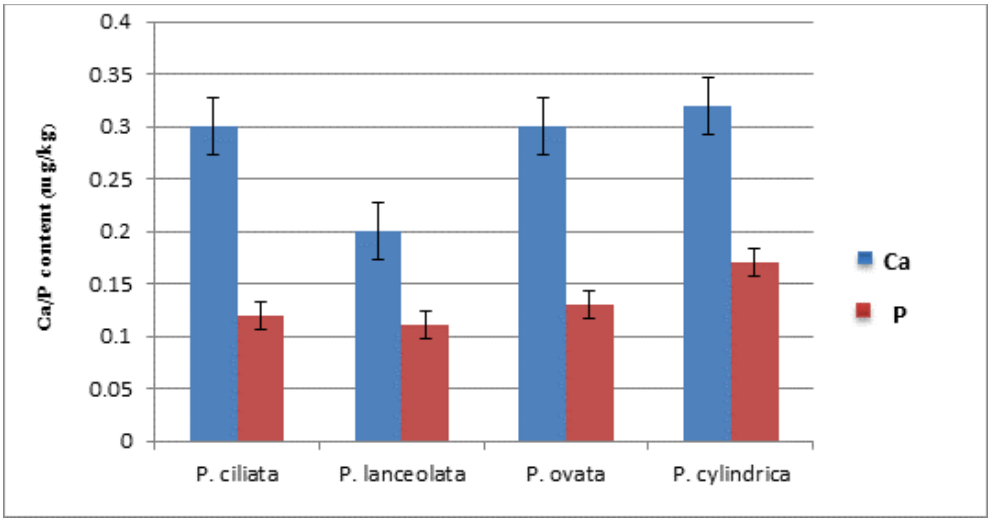

Fig. 7: Contents of calcium (Ca) and phosphorus (P) of some Plantago species of Ha'il, Saudi Arabia. Data are expressed as mean ± SE of replicate determinations (*n* = 3).

3.8 Acid Detergent Fiber (ADF)

Figure (8) shows the crude protein content of the species was ranged significantly from the lowest in *Plantago ciliata* (14%,DW) to the highest value in the rest of the samples (74%,DW), (64%, DW), (54%,DW) in the other species; *Plantago lanceolata*, *Plantago cylindrica* and *Plantago ovata* , respectively.

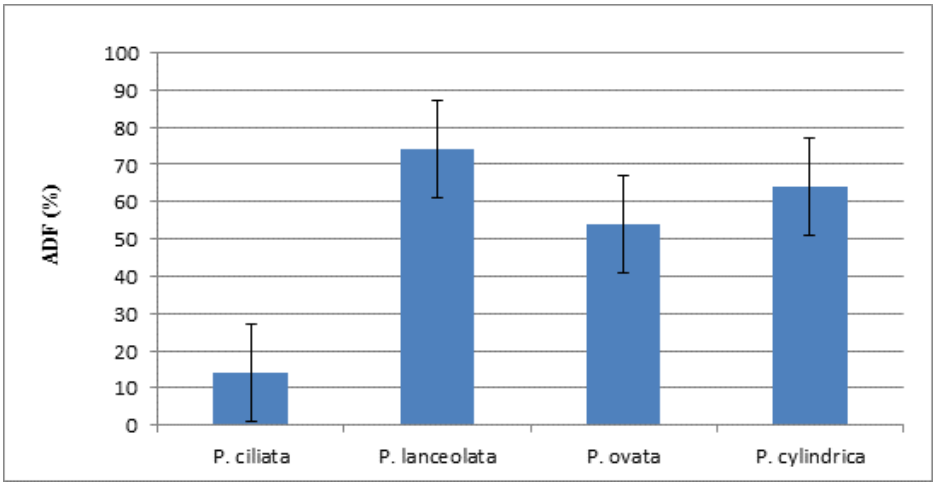

Fig. 8: Percentage of acid detergent fiber (ADF) of some Plantago species of Ha'il /Saudi Arabia. Data are expressed as mean ± SE of replicate determinations (*n*=3).

3.9 Total Digestible Nutrient (TDN)

Figure (9) shows that the percentage of crude fiber content of the species was ranged significantly from the highest in *Plantago ciliata* (86%,DW) to the lowest value in the rest of the samples (46%,DW), (36%,DW), (26%,DW) in the other species; *Plantago ovata*, *Plantago cylindrica* and *Plantago lanceolata,* respectively.

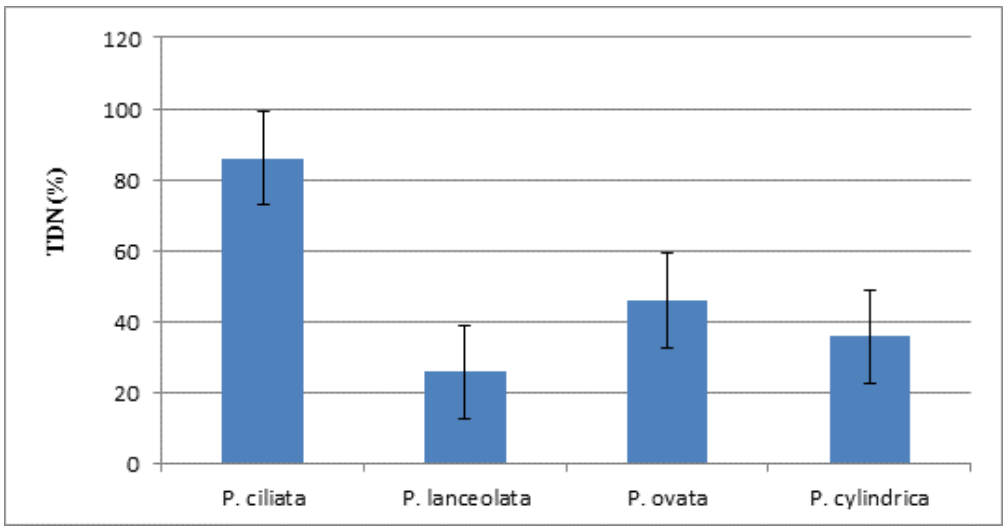

Fig. 9: Percentage of total digestible nutrient (TDN) of some Plantago species of Ha'il /Saudi Arabia. Data are expressed as mean ± SE of replicate determinations (*n*=3).

3.10 Phytochemical content

Phytochemical analysis of the aqueous solutions of *Plantago ciliata, Plantago lanceolata, Plantago ovata,* and *Plantago cylindrica* were evaluated as shown in Table 2. There are amounts of protein -xanthoprotein, tannins, cardiac glycosides, flavonoids, saponins, terpenoid, phenols, glycosides and saponins at varying degrees. Alkaloid was absent only in *Plantago cylindrica,* while cardiac glycosides were not detected in *Plantago lanceolata.* On the other hand, flavonoids were not observed in all species except for *Plantago ovata,* while in all species resins were not observed.

Table 2. Phytochemical analysis of Plantago species of Ha'il /Saudi Arabia.

Phyto-constituents	*Plantago ciliata*	*Plantago lanceolata*	*Plantago ovata*	*Plantago cylindrica*
Protein -xanthoprotein	+++	++	++	+
Tannins	+	+	+++	+
Alkaloid	++	+	+	-
Saponins	+	+	++	++
Cardiac glycosides	++	-	++	++
Terpenoid	++	+	+	+
Flavonoid	-	-	+	-
Phenols	+	+	+	+
Glycosides	+	+	+++	+
Resins	-	-	-	-

+: present, −: absent

+ (Low in abundance), ++ (Moderate in abundance), +++ (High in abundance)

4. DISCUSSION

As shown in the result section there are significant variations in the nutritional values and mineral content of the Plantago plant species, which could be attributed to the effect of many factors, including climate, species, soil type and plant phenology as suggested by Greene ***et al***. (1987). Also, Ahmed (2013) attributed such variations due to the degree of maturity of plants.

The moisture content of the Plantago plants in the current study varied from 29 to 52.29% (DW) which is relatively high for such plants that live under the arid conditions of Ha'il region. Therefore, such variation in moisture content between different species might be due to their physiological capability to retain water, degree of maturity and to the external enivironmental conditions such as rainfall seasonality and soil moisture (Rehman and Adnan 2018).

Ash content of the Plantago species in this study ranged from 7 to 16% (DW). Such variation could be explained by some factors including; degree of maturity of plants and soil properties that need to be explored further (Alghamdi, 2017).

Crude protein content of the samples varied from 10.68 to 14.63 (DW %), which is a relatively reasonable proportion compared to Alfalfa (16.50%) as mentioned by Ghaley ***et al***. (2012). However, such protein is present in the form of non-protein nitrogen, therefore, alternative sources of nitrogen should be supplemented to grazing animals' feed for better utilization and efficiently digestion nitrogen (Attia-Ismail, 2015).

Crude fat content of the current Plantago plants varied from 0.6 to 1.6%, (DW). This amount of fat is relatively low; although, it is reasonable as these plants live under dry climate of Ha'il as suggested by Rehman and Adnan (2018) who explained that greater contents of fat exist normally in wet region plants.

Crude fiber content of the current species ranged from 11.2 to 23.12 (DW %), which is relatively high compared to other forages such alfalfa (Ahmed ***et al.,*** 2013). Such high ratio of fiber might be due to the degree of maturity during sampling, as it has been well documented that when plants became older, the crude fiber tended to increase according to Ahmed ***et al.*** (2013).

The carbohydrates content of the current species varied from 11.64 to 24 % (DW), which is reasonable for grazing animals as they have microorganisms in their digestive system which are able to digest all the cellulose content of the forages (Hussain and Durrani, 2009).

Mineral content of plants, particularly calcium and phosphorus are important for the proper growth and development of the skeleton in grazing animals. They work closely together, therefore, they must be provided in the right ratio and level. According to Rasby ***et al***. (2011) feed dry matter for the grazing animals should contain an adequate ratio of calcium/phosphorous between 1.5:1 to 3:1. Therefore, all Plantago species of the current study seemed to be sufficient to provide a good source of calcium and phosphorus for grazing animals.

Acid Detergent Fiber (ADF) (Cellulose and Lignin content) of the Plantago species in the current study varied from 14 to 74%(DW) whereas, total digestible nutrients (TDN) ranged from 26 to 86%(DW). This variation could be affected by the maturation of plants as suggested by Andrighetto ***et al.*** (1993) who argued that the increased ADF in particular is linked to the increase in plant maturity.

Phytochemical results obtained in the current research were consistent with results from literature, for instance; investigations of *P. major* revealed the presence of various chemical constituents such as; flavonoids, caffeoyl phenylethanoind glycosides, iridoid glycosides, polyphenolic compounds (Zubair ***et al.,*** 2010). The bioactive compounds together with the nutrients detected in the Plantago plants species encourage the use of them for improving of health and production of farm animals as suggested by Sumon ***et al.*** (2014) who have concluded that medicinal plants may be supplemented to the diet to improve the nutritional efficiency of grazing animals. For the past few decades, a growing number of people have been drawn attention to alternative forms of medicine in response to disillusionment with the modern medical system. Many botanical, especially herbal, products have gained popularity for the treatment of ailments and diseases such as the common cold, wounds, hypertension, inflammation, viral infections, depression, insomnia, and even cancer (Blumenthal ***et al.***, 2006) due to their good sources of protein and minerals (Sano ***et al.,*** 2002).

5. CONCLUSION

The author assumes that this is the first study that has examined the nutritional value and phytochemical of four species of the Plantago genus that grown naturally in Ha'il region, Kingdom of Saudi Arabia. The findings of the current study showed that these species vary considerably in their nutritional value and phytochemical contents. Also, it revealed that some species have high to reasonable contents of protein, fat, fiber, carbohydrates, minerals and phytochemicals which make them potential local resources to be exploited as alternative forages in such dry-climate region like Ha'il. However, further research is needed in order to investigate the effect of some

important eco-physiological factors such as; plant growth stages, plant seasonal changes, drought and salinity on the suitability of those species as forages.

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Ameliorative Effect of α-tocopherol on *Capsicum Annuum* (L.) Plants Exposed to Short-Term Sea Water Stress

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ABSTRACT

Alpha-tocopherol (α-TOC); one of the important vitamins in plants, is considered as a non-enzymatic antioxidant .It plays an important role in ameliorating a number of abiotic stresses, including salinity. A pot experiment was conducted in 2017 at Albaha region, Saudi Arabiato study the ameliorative effect of α-TOC (2 mM)on sweet pepper (*Capsicum annuum* L., cv. 'California Wonder') plants under irrigation with diluted sea water (DSW). The DSW was obtained by mixing sea water (54.7 dS m^{-1}) with fresh water to decline the electrical conductivity to12.5 dS m^{-1}. Results show that short term irrigation with DSW significantly reduced growth and yield characteristics, photosynthetic pigment contents, relative water content (RWC), membrane stability index (MSI), contents of K^+ and Ca^{2+} and ratios of K^+/Na^+ and Ca^{2+}/Na^+, while increased the contents of proline, soluble sugars, α-TOC, and Na^+. However, exogenous α-TOC ameliorated the salt stress effects and significantly increased growth and yield characteristics, photosynthetic pigment contents, RWC, MSI, contents of K^+ and Ca^{2+}, ratios of K^+/Na^+ and Ca^{2+}/Na^+. It further increased the contents of proline, soluble sugars, and α-TOC, while significantly reduced Na^+ content compared to the corresponding controls. These results recommend the use of 2.0 m Mα-TOC as a commercial formulation to improve growth and productivity of sweet pepper plants exposed to short term saline (EC = 12.5 dS m^{-1}) water irrigation.

Keywords: Sweet pepper; salt stress; α-tocopherol; growth and yield; tissue health

1. INTRODUCTION

Sweet pepper (*Capsicum annuum* L.) is an important crop due to its economic importance and its nutritional value, and its fruits are an excellent source of bioactive products that are important for human health (Howard ***et al.***, 2000). Sweet pepper is classified as a moderately sensitive crop to salt stress (Lee, 2006).

Salinity is one of the major constrains, particularly in dry (arid and semi-arid) regions. It restricts plant growth and development because of its adverse effects on physiological, biochemical and molecular levels (Tester and Davenport, 2003). Salt stress can also disturb the photosynthetic processes by increase in the endogenous accumulation of Na^+, Cl^-, and other undesired ions, causing disturbance in water and osmotic potential. Where, high salinity reduces the soil water potential and causes physiological drought in plant growth medium (Yusuf ***et al.***, 2007). Plants grown under saline conditions change their metabolism to overcome this adverse environmental condition. They can adapt to salt stress through different mechanisms. Changes in morphological and developmental patterns, as well as biochemical responses are of these mechanisms (Bohnert ***et al.***, 1995).One mechanism adopted by plants to overcome salt stress is the accumulation of compatible osmolytes such as

freeproline and soluble sugars (Semida and Rady, 2014; Bargaz ***et al.***, 2016). The synthesis and accumulation of proline and soluble sugars by plant tissues during salt and/or water stress is an adaptive response (Rady ***et al.***, 2015). In addition, low molecular weight antioxidants like ascorbic acid, glutathione, α-tocopherol, etc., besides enzymatic antioxidants (i.e., superoxide dismutase, catalase, as corbate peroxidase, glutathione reductase, etc.) represent a major part of antioxidative defense system that act toalleviate salt stress damages and increase resistance to salt stress (Semida and Rady, 2014; Bargaz ***et al.***, 2016; Semida ***et al.***, 2016). Such mechanisms/systems may be induced or activated by spraying plants with antioxidants, including vitamins (Semida ***et al.***, 2014, 2016).

Vitamins are organic compounds used in trace amounts to maintain normal growth and correct development in all organisms. These compounds are considered as an essential part of the regulation of plant metabolism by acting as enzyme co-factors (Rady ***et al.***, 2015). One of them is α-tocopherol (α-TOC) that is a lipophilic membrane-located vitamin compound in chloroplasts (Semida ***et al.***, 2014; Rady ***et al.***, 2015). Theα-TOC is a lipid-soluble antioxidant, localizing the chloroplast envelope and thylakoid membranes of green plants (Matringe ***et al.***, 2008). It is synthesized exclusively in photosynthetic organisms (Della Penna, 2005). It has been postulated that α-TOC increases plant tolerance to the adverse effects of salt stress on crop performance (Rady ***et al.***, 2015; Semida ***et al.***, 2014, 2016).

Therefore, the objective of this study was to assess the response of sweet pepper plants exposed to a short term irrigation with diluted sea water (DSW) with EC = 12.5dS m^{-1} to foliar application of 2.0 m Mα-TOC. In addition, this study aimed to investigate the integrative effects of α-TOC and DSW on plant performance (growth and yield), nutrient status, cell and tissue health and activity of the non-enzymatic antoxidative defense system, including α-TOC in sweet pepper plants.

2. MATERIALS AND METHODS

2.1 Growth conditions and treatments

A three-replicated pot experiment was conducted in a wire-house at Albaha University (latitude 20° 17' 41"N, longitude 41° 38' 35"E), elevation 1651.88m above sea level, Albaha, Saudi Arabia. The climate of the study area is semiarid (Zabin and Howladar, 2015) and is characterized as follows: the mean annual temperature varies from a minimum of 17.8˚C and a maximum of 29.9˚C. The average annual rainfall is about 62.45 mm. The relative humidity min. 15% and max 87%, the mean wind speed around 6 Kts/Deg (PMEP, 2017).

Sweet pepper seedlings (45-day-old, had 6-7 leaves for each) were obtained and two healthy seedlings were transplanted in each 50 cm-diameter plastic pot, containing air-dried 12 kg of a sandy loam soil. According to the recommended doses of agricultural practices, nitrogen (N) as ammonium sulphate (20.5% N) at 2.5 g per pot, phosphorous (P) as calcium superphosphate (15.5% P_2O_5) at 1.5 g per pot, and potassium (K) as potassium sulphate (48% K_2O) at 1 g per pot were added to each pot before planting. In addition, further N doses (ammonium sulphate 20.5% N) were added at 30, 60, and 120 days after transplanting at 1.5 g per pot.

The experimental treatments were arranged in a completely randomized design as one level (12.5 dS m^{-1}) of diluted sea water(DSW)and one level (2 mM) of α-TOC(Hangzhou Toyond Biotech Co. Ltd., Zhejiang, P. R. China) and their combination (DSW × α-TOC), besides the control (Tap water), each with 20 replicates (pots) per treatment. Starting at 16 days after transplanting, all plants per treatment (n = 40) were sprayed two-times, at 6-day intervals with tap water or 2mMα-TOC. Theα-TOC at 2mM was chosen as the best level to apply based on a preliminary study in which we tested 1.0, 1.5, 2.0, 2.5 or 3.0 mMα-TOC (data not shown). In the control

treatment, plants (n = 40) were irrigated with tap water having an electrical conductivity (EC) of 0.34dS m^{-1} and sprayed with tap water in place of 2mMα-TOC. To induce salinity stress, sea water (EC = 54.7dS m^{-1}) was mixed with tap water (EC = 0.34dS m^{-1}) to obtain the used level of DSW (12.5dS m^{-1}). Batches of plants (n = 40) were then watered four consecutive times with an equal volume of DSW. The first DSW irrigation was applied with the first foliar application with α-TOC and the third DSW irrigation was applied with the second foliar application with α-TOC. The EC and pH values and the contents of cations and anions in the soil used for the experiments are shown in Table 1.The soil water-holding capacity was measured by saturating the soil in each pot with water and weighing it after it had drained for 48 h. The water-holding capacity of the soil in each pot was 36% (w/v) soil:water. Soil water contents were maintained at approx. 90% (w/v) of the soil water-holding capacity. The level of soil moisture was controlled by weighing each pot and any water loss was supplemented daily.

Table 1. Physico-chemical characteristics of a sandy loam soil prior to the experiments in two seasons.

Bulk density (g cm^{-3})	CEC ($cmol^{+}/kg$)	pH	EC (dS m^{-1})	OC*	N	P	K	Ca	Fe	Mn	Zn
				(g kg^{-1})				(mg kg^{-1})			
1.29	7.9	7.7	2.3	8.9	0.82	15	70	85	6.0	4.0	2.1

*OC, organic content.

2.2 Measurements

To measure growth and yield characteristics of sweet pepper plants, five sample pots were taken randomly from each treatment at 75 days after transplanting. Number of leaves per plant was counted and leaf area per plant (m^2) was assessed using a digital Planimeter. Plant dry weight (g) was measured after oven-drying at 70 °C for 48 h. At harvest, five plants from each treatment were taken and yield of pepper plants in terms of fruit number and fruit weight per plant were recorded.

Total chlorophylls and total carotenoids were extracted and determined according to the methods described by Arnon (1949) using 80% (v/v) acetone to homogenize samples, and then centrifugation at 10,000 × *g* for 10 min was performed. Absorbances of extracts were measured at 663, 645, and 470 nm using a UV-160A UV-visible recording spectrometer (Shimadzu, Kyoto, Japan).

Relative water content (RWC) of tissue was measured according to Hayat *et al.* (2007) using fully-expanded leaf discs. Discs were weighed (fresh mass; FM) and immediately floated on double-distilled water in Petri dishes for 24 h, in the dark, to saturate discs with water. Any adhering water was gently dried and the turgid mass (TM) was recorded. Dry mass (DM) was taken after drying the discs at 70°C until the constant weight. RWC was then calculated using the following formula:

$$\mathrm{RWC}(\%) = \left[\frac{(\mathrm{FM} - \mathrm{DM})}{(\mathrm{TM} - \mathrm{DM})}\right] \times 100$$

Membrane stability index of plant tissues (MSI) was determined according to the method of Rady (2011) using two equivalent samples of fully-expanded leaf tissues. First sample was placed in test-tube containing double-distilled water. The content of the test-tube was heated at 40°C in a water bath for 30 min, and the electrical conductivity (EC1) of the solution was recorded using a conductivity bridge. Second sample was boiled at 100°C for 10 min, and the conductivity was measured (EC2), and MSI was calculated using the formula:

$$\mathrm{MSI}(\%) = \left[1 - \left(\frac{\mathrm{EC1}}{\mathrm{EC2}}\right)\right] \times 100$$

Free proline was determined following the method of Bates ***et al***. (1973). Samples were grinded in 3% (v/v) sulphosalicylic acid, and centrifugation at 10,000 × *g* for 10 min was then done. In a test-tube, a 2-ml of freshly prepared acid-ninhydrin solution was added to 2 ml of the supernatant. The tubes were incubated in a water bath at 90ºC for 30 min, and the reactions were terminated in an ice-bath. Reaction mixtures were then extracted with 5 ml of toluene and vortex-mixed for 15 s. At room temperature, the tube was allowed to stand for at least 20 min in the dark to separate the toluene and aqueous phases. The toluene phase was then collected carefully into a test tube and the absorbance of the toluene phase was read at 520 nm using a Bauschand Lomb-2000 Spectronic Spectrophotometer.

Total soluble sugars were determined according to Irigoyen ***et al***. (1992). Samples were homogenized in 5 ml of 96% (v/v) ethanol, and then washed with 5 ml 70% (v/v) ethanol. The extracts were centrifuged at 3500 × g for 10 min, and the supernatants were stored at 4°C prior to determination. Reaction mixture of 0.1 ml of the ethanolic extract and 3 ml of freshly-prepared anthrone reagent [150 mg anthrone plus 100 ml of 72% (v/v) sulphuric acid] were placed in a boiling water bath for 10 min, and was then cooled. The absorbance was recorded at 625 nm using a Bauschand Lomb-2000 Spectronic Spectrophotometer.

Alpha-tocopherol (α-TOC) concentration was measured using 900 ml of extraction solvent (*n*-hexane-ethyl acetate, *n*-hexane) that was mixed with 100 ml of ethyl acetate and then 20 mg of butylated hydroxytoluene (BHT) was dissolved in this solvent mixture. Using R-TOC, standard solutions (20 – 200 µg/ml) were prepared from stock solution (50 mg/100 ml *n*-hexane). According to the method of Konings ***et al.*** (1996), samples were prepared and saponified. Samples were sliced and dried in an oven at 40 °C and homogenized, and then 5 g from each sample was suspended in 30 ml of water in a 500-ml conical flask. To the flask, 21 g of KOH dissolved in 100 ml of ethanol was added and then 0.25 g of ascorbic acid g^{-1} test portion was added for protecting from oxidation and mixed. At 80 °C, saponification was done for 40 min and the samples were immediately cooled to room temperature. Water (300 ml) was added to bring the ethanol/water ratio to 0.3 and then *n*-hexane/ethyl acetate [9:1 (3 × 100 ml)] was added, and the mixtures were extracted 3 times in a separatory funnel. Organic phases were combined and washed with 100-ml portions of water until free of alkali that was determined by where the reaction of washes to phenolphthalein was neutral (no visible pink color). Organic phases were then filtered through anhydrous sodium sulphate into a beaker. The filtrates were evaporated to dryness under reduced pressure (at 40 °C). The residues were dissolved each in 20 ml of *n*-hexane (HPLC grade) and stored in a freezer at –20 °C. The αTOC was determined on a HPLC system using a Waters Bondapak C_{18} reverse-phase column. The mobile phase (methanol/water 94:6) was used at a flow rate of 1.5 ml min^{-1} and the UV detector was set at 292 nm (Ching and Mohamed, 2001).

Contents of Na^+ and K^+ were determined as follows: 0.2 g of dried leaf was digested with sulphuric acid in the presence of H_2O_2 (Wolf, 1982). The mixture was then diluted with distilled water. The total leaf concentrations of Na^+ and K^+ were measured directly using Flame Spectrophotometry (Lachica ***et al.***, 1973). The content of Ca^{2+} was determined using a Perkin-Elmer Model 3300 Atomic Absorption Spectrophotometer (Chapman and Pratt, 1961). Results were calculated and expressed as mg g^{-1} dry weight.

2.3 Statistical analysis

The completely randomized design was the layout for the current work. Data were statistically analyzed using ANOVA followed by Tukey's HSD test (SPSS 14.0; SPSS Chicago, IL, USA). Significant differences were analyzed based on $P \leq 0.05$ between four means of four treatments.

3. RESULTS

Data presented in Table 2 show that growth and yield characteristics (i.e., number of leaves per plant, leaf are per plant, plant dry weight, number of fruits per plant and fruit yield per plant) of sweet pepper plants were significantly increased with foliar spray of α-tocopherol (α-TOC) when plants irrigated with tap water compared to the normal control (irrigated with tap water). Under short term irrigation with diluted sea water (DSW), the pepper growth and yield characteristics were significantly reduced compared to the normal control. However, application of α-TOC as foliar spray significantly increased these characteristics compared to the salt-stressed control (irrigated with DSW). These increases were 64% for number of leaves per plant, 71% for leaf area per plant, 67% for plant dry weight, 100% for number of fruits per plant, and 124% for fruits weight per plant, respectively.

Table 2. Effect of α-tocopherol (TOC; 2 mM) application on some growth and yield characteristics of *Capsicum annuum* plants irrigated with diluted sea water

Treatments	Leaves No. plant^{-1}	Leaf area plant^{-1} (m^2)	Plant dry weight (g)	Fruit No. plant^{-1}	Fruit yield plant^{-1} (g)
Tap water (control)	49 ± 5 b	0.14 ± 0.02 b	69 ± 7 b	12 ± 2 b	360 ± 32 b
Tap water + $TOC_{2.0}$	54 ± 5 a	0.16 ± 0.02 a	74 ± 7 a	14 ± 2 a	400 ± 38 a
Sea water ($Salin_{12.5}$)	25 ± 3 d	0.07 ± 0.00 d	36 ± 4 d	5 ± 1 d	98 ± 10 d
$Salin_{12.5}$ + $TOC_{2.0}$	41 ± 4 c	0.12 ± 0.01 c	60 ± 6 c	10 ± 2 c	220 ± 19 c

Values are means (n = 5) and differences between means were compared by least-significant difference test (LSD; $P \leq 0.05$). Means followed by different letters are significantly different.

Data shown in Table 3 show that the contents of leaf photosynthetic pigments (i.e., total chlorophylls and total carotenoids) of sweet pepper plants were significantly increased, while relative water content (RWC) and membrane stability index (MSI)were not affected by foliar spray of α-TOC when plants irrigated with tap water compared to the normal control. Under short term irrigation with DSW, the contents of total chlorophylls and total carotenoids, RWC and MSI were significantly decreased compared to the normal control. However, application of α-TOC as foliar spray significantly increased the contents of total chlorophylls and total carotenoids, RWC and MSI compared to the salinized controls. These increases were 80% for total chlorophylls, 56% for total carotenoids, 52% for RWC, and39% for MSI.

Table 3. Effect of α-tocopherol (TOC; 2 mM) application on leaf contents of photosynthetic pigments (mg g^{-1} FW), relative water content (RWC), and membrane stability index (MSI) of *Capsicum annuum* plants irrigated with diluted sea water.

Treatments	Total chlorophylls	Total carotenoids	RWC (%)	MSI (%)
Tap water (control)	1.92 ± 0.05 b	0.55 ± 0.01 b	74 ± 2 a	68 ± 2 a
Tap water + $TOC_{2.0}$	2.08 ± 0.07 a	0.65 ± 0.01 a	78 ± 2 a	71 ± 2 a
Sea water ($Salin_{12.5}$)	0.89 ± 0.03 d	0.32 ± 0.00 d	42 ± 1 c	44 ± 1 c
$Salin_{12.5}$ + $TOC_{2.0}$	1.60 ± 0.04 c	0.50 ± 0.01 c	64 ± 2 b	61 ± 1 b

Values are means (n = 5) and differences between means were compared by least-significant difference test (LSD; $P \leq 0.05$). Means followed by different letters are significantly different.

Data shown in Table 4 show that the contents of antioxidants/osmoprotectants (i.e., free proline and soluble sugars) were not affected, while the content of the antioxidant α-TOC was significantly increased by foliar spray of α-TOC when plants irrigated with tap water compared to the normal control. Under short term irrigation with DSW, the contents of free proline, total soluble sugars and α-TOC were significantly increased compared to the normal control. Application of α-TOC as foliar spray significantly further increased the contents of these osmoprotectants/antioxidants compared to the salinized controls. These increases were 58 and 20% for free proline, 130 and 44% for total soluble sugars, and 158 and 63% for α-TOC compared to the normal and salinized controls, respectively.

Table 4. Effect of α-tocopherol (TOC; 2 mM) application on leaf contents of free proline(μg g^{-1} DW), total soluble sugars (mg g^{-1} DW), and α-tocopherol (α-TOC; μg g^{-1} DW) of *Capsicum annuum* plants irrigated with diluted sea water.

Treatments	Free proline	Soluble sugars	α-TOC
Tap water (control)	62 ± 1.1 c	20 ± 0.4 c	24 ± 0.3 d
Tap water + $TOC_{2.0}$	64 ± 1.3 c	21 ± 0.4 c	30 ± 0.3 c
Sea water ($Salin_{12.5}$)	82 ± 1.6 b	32 ± 0.7 b	38 ± 0.4 b
$Salin_{12.5}$ + $TOC_{2.0}$	98 ± 1.8 a	46 ± 0.9 a	62 ± 0.5 a

Values are means (n = 5) and differences between means were compared by least-significant difference test (LSD; $P \leq 0.05$). Means followed by different letters are significantly different.

Data shown in Table 5 exhibit that the contents of K^+, Ca^{2+} and Na^+, and the ratios of K^+/Na^+ and Ca^{2+}/Na^+ of sweet pepper plants were not affected by foliar spray of α-TOC when plants irrigated with tap water compared to the normal control. Under short term irrigation with DSW, the contents of K^+ and Ca^{2+}, and the ratios of K^+/Na^+ and Ca^{2+}/Na^+ were significantly decreased, while the content of Na^+ was significantly increased compared to the normal control. However, application of α-TOC as foliar spray significantly increased the contents of K^+ and Ca^{2+}, and the ratios of K^+/Na^+ and Ca^{2+}/Na^+, while significantly decreased the content of Na^+ compared to the salt-stressed controls. The increases in the contents of K^+ and Ca^{2+} were 91 and 55%, respectively, and the ratios of K^+/Na^+ and Ca^{2+}/Na^+ were 332 and 247%, respectively. The reduction in the content of Na^+ was 55%.

Table 5. Effect of α-tocopherol (TOC; 2 mM) application on leaf contents of K^+ and Ca^{2+}(mg g^{-1} DW), and the ratios of K^+/Na^+ and Ca^{2+}/Na^+in *Capsicum annuum* plants irrigated with diluted sea water

Treatments	K^+	Ca^{2+}	Na^+	K^+/Na^+ ratio	Ca^{2+}/Na^+ ratio
Tap water (control)	23 ± 0.6 a	9.6 ± 0.2 a	4.2 ± 0.1 c	5.48 ± 0.1 a	2.29 ± 0.0 a
Tap water + $TOC_{2.0}$	23 ± 0.6 a	9.8 ± 0.2 a	4.1 ± 0.1 c	5.61 ± 0.1 a	2.39 ± 0.0 a
Sea water ($Salin_{12.5}$)	11 ± 0.3 c	5.8 ± 0.1 c	18.2 ± 0.5 a	0.60 ± 0.0 c	0.32 ± 0.0 c
$Salin_{12.5}$ + $TOC_{2.0}$	21 ± 0.5 b	9.0 ± 0.2 b	8.1 ± 0.2 b	2.59 ± 0.0 b	1.11 ± 0.0 b

Values are means (n = 5) and differences between means were compared by least-significant difference test (LSD; $P \leq 0.05$). Means followed by different letters are significantly different.

4. DISCUSSION

In the arid and semiarid regions that are characterized by water scarcity, salt stress adversely affects different processes during seed germination, growth and flowering that reflect in plant productivity (Semida ***et al.***, 2016). These saline effects occur by stimulating the overproduction of reactive oxygen species (ROS) through various organelles and enzymes and to avoid these effects, plants adopt several strategies, including ion homeostasis, osmotic adjustment, and enhancing the antioxidant defense system (Xiong and Zhu, 2002). In the current study, the reduced plant growth and yield (Table 2) under the adverse conditions of the short term irrigation with diluted sea water (DSW; EC = 12.5dS m^{-1}) could be attributed to the osmotic effect of salt stress, causing a disturbance in the water balance of the stressed plants that are clearly shown in Table 3 (strongly reduced RWC). This imbalance tissue water content leads to stomatal closure, ionic imbalance (Table 5), reduction in photosynthetic pigments (Table 3) and consequently photosynthesis process, accumulation of toxic ions and consequently inhibition of growth and productivity (Table 2) (Semida and Rady, 2014; Semida ***et al.***, 2014, 2016).

Salt stress negatively affects plant growth by causing disruptions in various physiological and biochemical processes, including photosynthesis, antioxidant capacity and ion homeostasis (Semida ***et al.***, 2016), resulting in damages of growing cells which, therefore, cannot perform their functions (Chen and Murata, 2000). Spraying the sweet pepper seedlings with 2.0mMα-TOC two times significantly improved all plant growth and yield characteristics, alleviating the harmful effects of salt stress on growth and yield of pepper plants and increased plant dry matter accumulation (Table 2). The α-TOC as an antioxidant, deactivates photosynthesis-derived ROS, and prevents the increase in lipid peroxidation by scavenging lipid peroxyl radicals in thylakoid membranes (Liu ***et al.***, 2008; Semida ***et al.***, 2016). Levels of α-TOC have been found to change differentially in response to environmental restrictions, depending on the magnitude of the stress and species-sensitivity to stress. The α-TOC considers an important part of the plant defense machinery, maintaining the integrity and normal function of the photosynthetic apparatus (Liu ***et al.***, 2008). Foyer and Noctor (2005) concluded that α-TOC acts directly to neutralize superoxide radicals ($O_2^{\bullet-}$) or singlet oxygen ($^1O_2$) in plant cells. It also affects many physiological processes positively under saline conditions such as the regulation of growth, differentiation and metabolism of plants and the increase in the physiological availability of water and nutrients (Semida ***et al.***, 2016). It has been reported that applied α-TOC protects metabolic processes against H_2O_2 and other toxic derivatives of oxygen, affects many enzyme activities, minimizes the damage caused by oxidative processes through synergic function with other antioxidants and stabilizes tissue membranes, and consequently obtaining healthy plant growth and satisfactory yield under salt stress conditions (Semida ***et al.***, 2016). These positive effects of α-TOC were performed by the increase in its endogenous content in the current study (Table 4).

Salt stress, in the current study, adversely affected photosynthesis by the reduction in leaf photosynthetic pigments (chlorophylls and carotenoids; Table 3), while α-TOC application repaired the photosynthetic machinery from salt-induced ROS, and increased chlorophyll and carotenoid contents. The reduced content of chlorophylls under salt stress generated by irrigation of pepper plants with DSW might have been due to that salt induced increase in the activity of chlorophyll degrading enzyme chlorophyllase (Rao and Rao, 1981).

Reduced performances (growth and yield) of sweet pepper plants grown under salt stress have been associated with the reduction in water potential that decreased the relative water content (RWC) and membrane stability index (MSI), while the application of α-TOC weakened these adverse effects and increased RWC and MSI (Table 3). Application of α-TOC enabled plant tissues to maintain high levels of RWC by regulating the leaf osmolality (free proline and soluble sugars; Table 4), alleviating the negative effects of salt stress and reflecting in

the increase in MSI. The increase in water potential and osmotic potential might help the stabilization of protein and increases photosynthesis (Ashfaque ***et al***., 2014). The exogenous application of α-TOC exhibited alleviation in the deleterious salt effects and increased RWC and MSI, maintaining turgidity of tissue cells for healthy metabolic processes and membranes integrity. In addition, free proline and soluble sugar contents were increased with foliar application of α-TOC acting as solutes for intercellular osmotic adjustment and further important factors of adaptation to salinity (Semida ***et al***., 2016). This result is found to be in a parallel line with the results of the present study (Table 4). These increased contents of free proline and soluble sugars that act as osmoprotectants supported the crucial role of α-TOC as an antioxidant in alleviating the deleterious salt effects. In the present study, the increased proline content was observed in pepper leaves under salt stress, and was further increased after the application of α-TOC. The increase in leaf proline content under saline stress might be caused by increased proline synthesis from glutamate, decreased use for protein synthesis, or enhanced protein turnover. Thus, proline may be the major source of energy and N during immediate post-stress metabolism. The accumulated proline supplies plants with energy for growth and survival, thereby increasing the salt tolerance (Gad, 2005). Application ofα-TOC alleviated the salt stress injury and the increased content of proline accompanied with the increase in total soluble sugar content. Since proline biosynthesis is a highly energy-demanding process, reduced proline synthesis could benefit plants by saving energy to cope with stress (Gad, 2005). Total soluble sugars are considered as key osmolytes for osmotic adjustment. Accumulation of total soluble sugars is a common phenomenon under stress conditions (Murakeozy ***et al***., 2003). Irrigation of pepper plants with DSW significantly increased total soluble sugars content compared to normal control plants. Haq ***et al***. (2011) reported an increase in total soluble sugars under salt stress, which plays an important role in osmoregulation and reduced the osmotic potential.

Salinity caused both hyper-ionic and hyper-osmotic stress, leading to plant death (Hasegawa ***et al***., 2000). It has been reported that plants grown under saline conditions are affected in three ways: reduced water potential in the root zone, causing water deficit stress; phytotoxicity of Na^+ and Cl^- ions; and nutrient imbalances due to lowered uptake and transport of nutrients such as K^+ and Ca^{2+} studied in the current study (Table 5). Na^+ ions compete with K^+ ions for the binding sites essential for cellular functions (Munns, 2002). However, data in Table 5 showed that irrigation of pepper plants with DSW caused significant increases in Na^+ ions content in leaves, with significant decreases in K^+ and Ca^{2+}ions contents, and in the $K^+/Na^+$and Ca^{2+}/Na^+ratios. The K^+ ions are the main cation and are an important component of the osmotic potential of cells (Reggiani ***et al***., 1995).Exogenous spray application of 2.0 mMα-TOC alleviated the harmful effects of salinity on ions (Ca^{2+} and K^+) contents due to the reduction in Na^+ ion accumulation (Table 5), as well as the increase in the contents of Ca^{2+} and K^+ led to the increase in the $K^+/Na^+$and Ca^{2+}/Na^+ ratios when compared with the salinized controls without α-TOC treatment. The positive effects of α-TOC arose through its role in increasing osmotic tolerance and/or through regulating processes such as the absorption of nutrients from the soil solution. In addition, the beneficial effects of α-TOC may be due to its roles in improving membrane permeability and increasing soluble protein contents, which protected membranes and membrane-bound enzymes. The α-TOC thus protected the plants against salt toxicity through its roles in maintaining the structural integrity of the plasma membrane and controlling the uptake of Na^+ and other toxic ions (Buschmann and Lichtenthaler, 1979).

Alpha-TOC acts as membrane stabilizers and multifaceted antioxidant that scavenge the ROS. It reacts with peroxy radicals formed in the bilayer as they diffuse to the aqueous phase, scavenging cytotoxic H_2O_2, reacts non-enzymatically with other ROS such as singlet oxygen, superoxide radical and hydroxyl radical, and stabilizes membrane structures (Blokhina ***et al***., 2003). In addition, α-TOC has appeared to play a major role in chloroplastic antioxidant network of plants, contributing to preserve an adequate redox station in chloroplasts, and to maintain thylakoid membrane structure and function during plant development and in plant responses to stress (Munne´-Bosch, 2005). Salt stress tolerance in pepper plants, in this study, was improved by foliar application of

α-TOC that was effective in alleviating the water salinity stress by better chlorophyll, nutrients and osmoprotectants contents, and plant growth and productivity. This might be attributed to cytokinin mediated stay green effect in leaves. Findings of the present study suggested that the exogenous application of α-TOC, particularly at the level of 2.0mM, improves the expression of stress–response genes and increases salt stress tolerance in pepper plants. In addition, inducing the expression of ROS-related stress–response genes by α-TOC application is an effective means of enhancing resistance to subsequent stress (Rady ***et al.***, 2015; Semida ***et al.***, 2016).

Results of the current study recommend the use of 2.0 mM α-TOC as a commercial formulation to improve the growth and productivity of sweet pepper plants when exposed to short term saline water irrigation (EC = 12.5 dS m^{-1}).

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CFD Analysis of Three Dimensional Natural Convection and Entropy Generation in Triangular Cavity with Inserted Isothermal Heater

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ABSTRACT

A three-dimensional numerical analysis of laminar natural convection with entropy generation in an air filled triangular enclosure with inserted isothermal heater at the bottom wall has been carried out using finite volume method. The aim of the study is to investigate how buoyancy forces influence air flow and temperature patterns inside the cavity cooled on its inclined wall while all other walls are assumed to be perfect thermal insulators. Rayleigh number is the main parameter which varies from 10^3 to 10^5 and Prandtl number is fixed at Pr =0.71. Results are reported in terms of particles trajectories, iso-surfaces of temperature, mean Nusselt number entropy generated and Bejan number. It has been found that the value of Rayleigh number is effective on temperature distribution, flow field and heat transfer.

Keywords: 3D; CFD; Natural convection; entropy generation; inserted heater; Rayleigh number; Nusselt number.

1. INTRODUCTION

Analysis of natural convection flow and heat transfer in enclosures plays important role in many diverse applications including solar collectors, building heating and ventilation, cooling electronical devices, cryogenic storage, nuclear reactor design and furnace design. Cooling of electronic equipment must be considered when designing such systems. In the open literature, many studies have appeared on natural convection in triangular enclosures due to its wide applications. The pioneers of natural convection studying in triangular cavities are Flack (1983) and Poulikakos and Bejan (1983a, 1983b). Then, Asan and Namli (2000, 2001) modeled the winter and summer day boundary conditions inside a roof of triangular cross-section. Joudi ***et al***. (2004) studied the performance of a prism shaped storage solar collector with a right triangular cross sectional area for the hot inclined wall and well insulated bottom and vertical walls. It was found that, early in the day, the temperature distribution is symmetric due to the low velocity, which is insufficient to circulate the fluid within the system. However, as the day progressed, the convective effects become more prominent leading to the distortion of isotherms. Further, it was found that the insertion of a horizontal partition within the storage collector enhances stratification of the water and renders higher mean tank temperature and higher stored energy. Ridouane ***et al.*** (2005) investigated the laminar natural convection in the air filled right-angled triangular enclosure with the hot vertical wall, cold inclined wall and adiabatic horizontal wall. It was found that, the heat transfer rate within the enclosure enhances largely with the decrease in both the apex angle and Rayleigh number.

Oztop ***et al.*** (2007) examined the convective heat transfer and fluid flow in a shed roof with or without eave for the summer boundary conditions. It was observed that the heat transfer rate from the inclined wall to the

bottom wall increases as the eave length increases. Also, it was found that the presence of the eave in the shed roof increases the heat transfer rate. Varol ***et al.*** (2006) carried out the natural convection problem with flush mounted heater on one wall of a triangular cavity. Governing parameters on heat transfer and flow fields are aspect ratio of triangle, location of heater, length of heater and Rayleigh number. They observed that the most important parameter on heat transfer and flow field is the position of heater which can be a control parameter for their system. Salmun (1995) reported convection patterns in a triangular enclosure filled with air (Pr= 0.72) or water (Pr= 7.1) for various aspect ratios in the presence of the hot bottom wall, cold hypotenuse and adiabatic vertical wall. It was observed that, at the low Ra, the changes in the aspect ratio had the negligible effect on the stream function and isotherms within the enclosure. However, the changes in the aspect ratio do affect the flow pattern and temperature fields significantly at the high Ra.

The fluid motion is found to be more intense in the right half of the enclosure and hence, the size of streamline circulation cells is observed to increase in size near those regions. Sojoudi ***et al.*** (2016) carried out the numerical simulations in order to study the unsteady air flow and heat transfer in a partitioned triangular cavity which was differentially heated from the left inclined wall. Also, an additional heat source was placed at the bottom wall of the triangular cavity. It was found that the thermal boundary layer thickness is increased along the left wall for the greater heater size and that the variation of Ra does not have any significant effect on the heat transfer rate of the left wall which decreases with time. A sizable amount of other related studies can be found in the literature review (Basak ***et al.***, 2007; Roy ***et al.***, 2008; Kent, 2009).

Moreover, only limited attention has been paid to the study of three-dimensional transverse flow which is primordial when dealing with the enhancement of heat transfer. The paramount aim of this work has been to numerically investigate the diffusive natural convection heat transfer and fluid flow in a three-dimensional air filled triangular enclosure with inserted isothermal heater.

2. MATHEMATICAL FORMULATION

2.1 Physical model

Physical model is presented in Fig. 1 with its specified coordinate system and boundary conditions. Indeed, the considered problem is three-dimensional natural convection and entropy generation in an air filled triangular cavity with inserted isothermal heater at the bottom wall. The analyzed cavity is cooled on its inclined wall while remaining walls are assumed to be insulated.

2.2 Governing Equations and Numerical Solution

As numerical method we had recourse to the vorticity-potential vector formalism $(\vec{\psi} - \vec{\omega})$ which allows, in a three-dimensional configuration, the elimination of the pressure, which is a delicate term to treat. To eliminate this term one applies the rotational to the equation of momentum. More details on this 3-D formalism can be found in the work of Kolsi ***et al.*** (2007).

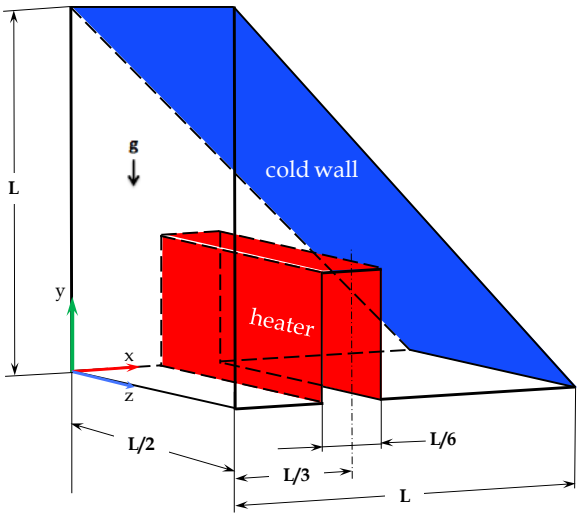

Fig. 1: Schematic of an air filled triangular enclosure

The potential vector and the vorticity are respectively defined by the two following relations:

$$\vec{\omega}' = \vec{\nabla} \times \vec{V}' \quad \text{and} \quad \vec{V}' = \vec{\nabla} \times \vec{\psi}' \tag{1}$$

After adimensionalisation the system of equations controlling the phenomenon becomes:

$$-\vec{\omega} = \nabla^2 \vec{\psi} \tag{2}$$

$$\frac{\partial \vec{\omega}}{\partial t} + (\vec{V}.\nabla)\vec{\omega} - (\vec{\omega}.\nabla)\vec{V} = \Delta\vec{\omega} + Ra.\Pr.\left[\frac{\partial T}{\partial z};0;-\frac{\partial T}{\partial x}\right] \tag{3}$$

$$\frac{\partial T}{\partial t} + \vec{V}.\nabla T = \Delta T \tag{4}$$

With: $\Pr = \frac{\nu}{\alpha}$ and $Ra = \frac{g.\beta.\Delta T.L^3}{\nu.\alpha}$

Boundary conditions for considered model are given as follows:

Temperature:

$T = 1$ on the inserted heater and $T = 0$ on the right inclined wall.

$\frac{\partial T}{\partial n} = 0$ on all other walls (adiabatic).

Velocity:

$V_x = V_y = V_z = 0$ on all walls

The generated entropy is written in the following form as: $S'_{gen} = -\frac{1}{T'^2}.\vec{q}.\vec{\nabla}T' + \frac{\mu}{T'}.\phi'$

The first term represents the generated entropy due to temperature gradient and the second that due to the friction effects.

$$\vec{q} = -k.\vec{grad}T$$

The dissipation function is written in incompressible flow as:

$$\phi' = 2\left[\left(\frac{\partial V'_x}{\partial x'}\right)^2 + \left(\frac{\partial V'_y}{\partial y'}\right)^2 + \left(\frac{\partial V'_z}{\partial z'}\right)^2\right] + \left(\frac{\partial V'_y}{\partial x'} + \frac{\partial V'_x}{\partial y'}\right)^2 + \left(\frac{\partial V'_z}{\partial y'} + \frac{\partial V'_y}{\partial z'}\right)^2 + \left(\frac{\partial V'_x}{\partial z'} + \frac{\partial V'_z}{\partial x'}\right)^2 \quad (5)$$

From where the generated entropy is written:

$$S'_{gen} = \frac{k}{T'^2_0}\left[\left(\frac{\partial T'}{\partial x'}\right)^2 + \left(\frac{\partial T'}{\partial y'}\right)^2 + \left(\frac{\partial T'}{\partial z'}\right)^2\right] + 2\frac{\mu}{T_0}\left\{\begin{array}{l}\left[\left(\frac{\partial V'_x}{\partial x'}\right)^2 + \left(\frac{\partial V'_y}{\partial y'}\right)^2 + \left(\frac{\partial V'_z}{\partial z'}\right)^2\right] \\ + \left(\frac{\partial V'_y}{\partial x'} + \frac{\partial V'_x}{\partial y'}\right)^2 + \left(\frac{\partial V'_z}{\partial y'} + \frac{\partial V'_y}{\partial z'}\right)^2 + \left(\frac{\partial V'_x}{\partial z'} + \frac{\partial V'_z}{\partial x'}\right)^2\end{array}\right\} \quad (6)$$

After adimensionalisation one obtains generated entropy number (dimensionless local entropy generated) which is written in the following way:

$$N_s = S'_{gen}\frac{1}{k}\left(\frac{LT_0}{\Delta T}\right)^2 \quad (7)$$

From where:

$$N_s = \left[\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial y}\right)^2 + \left(\frac{\partial T}{\partial z}\right)^2\right] + \varphi.\left\{2\left[\left(\frac{\partial V_x}{\partial x}\right)^2 + \left(\frac{\partial V_y}{\partial y}\right)^2 + \left(\frac{\partial V_z}{\partial z}\right)^2\right] + \left[\begin{array}{l}\left(\frac{\partial V_y}{\partial x} + \frac{\partial V_x}{\partial y}\right)^2 \\ + \left(\frac{\partial V_z}{\partial y} + \frac{\partial V_y}{\partial z}\right)^2 + \left(\frac{\partial V_x}{\partial z} + \frac{\partial V_z}{\partial x}\right)^2\end{array}\right]\right\} \quad (8)$$

With $\varphi = \frac{\mu\alpha^2 T_m}{L^2 k\Delta T^2}$ is the irreversibility coefficient.

The first term of N_s represents the local irreversibility due to the temperatures gradients, it is noted $N_{s\text{-}th}$. The second term represents the contribution of the viscous effects in the irreversibility it is noted $N_{s\text{-}fr}$. Ns give a good idea on the profile and the distribution of the generated local dimensionless entropy. The total dimensionless generated entropy is written:

$$S_{tot} = \int_v N_s\, dv = \int_v \left(N_{s-th} + N_{s-fr}\right)dv = S_{th} + S_{fr} \quad (9)$$

Bejan number (Be) is the ratio of heat and mass transfer irreversibility to the total generated entropy as:

$$Be = \frac{S_{th} + S_{dif}}{S_{th} + S_{fr} + S_{dif}} \tag{10}$$

Dimensionless irreversibilities distribution ratios (φ_1 , φ_2 and φ_3), are given by:

$$\varphi_1 = \frac{\mu\alpha^2 T_0}{L^2 k \Delta T^2} \; ; \; \varphi_2 = \frac{RDT_0}{kC_0}\left[\frac{\Delta C'}{\Delta T'}\right] ; \; \varphi_3 = \frac{RD}{k}\left[\frac{\Delta C'}{\Delta T'}\right] \tag{11}$$

The local and average Nusselt at the cold inclined wall are given by:

$$Nu = \frac{\partial T}{\partial n} \quad \text{and} \quad Nu_m = \int_0^{\sqrt{2}L} \int_0^{L} Nu \, dn \, dz \tag{12}$$

With: $\vec{n}$ is the unit vector normal to the cold inclined wall.

It should be noted that numerical analysis has been developed using an in-house computational code on the basis of FORTRAN programming language. The control volume finite difference method is used to discretize governing equations [(2)-(4)] and (8) respectively. The central-difference scheme is used for treating convective terms while the fully implicit procedure is used to discretize the temporal derivatives. The grids are considered uniform in all directions with clustering nodes on boundaries. The successive relaxation iteration scheme is used to solve the resulting non-linear algebraic equations.

A computer program written for a regular grid was improved to handle the irregularly shaped computational domain using the blocked-off method as described By Patankar (1981). In this technique, the whole region is divided into two active and inactive (blocked-off regions) parts. By this technique, the surface of inclined step in the present analysis is approximated by a series of fine cubic steps. It is obvious that using fine grids in the interface region between active and inactive zones causes to have an approximated boundary which is more similar to the true boundary. According to the blocked-off technique, known values of the dependent variables must be established in all inactive control volumes. If the inactive region represents a stationary solid boundary as in the case, the velocity components in that region must be equal to zero, and a known temperature (isothermal boundaries) must be established in the inactive control volumes. The control volumes, which are inside the active region, are designated as (1) and otherwise they are (0). The time step (10^{-4}) and spatial mesh (81 $\times 81 \times 41$) are utilized to carry out all the numerical tests. The solution is considered acceptable when the following convergence criterion is satisfied for each step of time:

$$\sum_{i}^{1,2,3} \frac{\max\left|\psi_i^n - \psi_i^{n-1}\right|}{\max\left|\psi_i^n\right|} + \max\left|T_i^n - T_i^{n-1}\right| \le 10^{-4} \tag{13}$$

3. VALIDATION

The present model, in the form of an in-house computational fluid dynamics (CFD) code, has been validated successfully against the work of Yesiloz and Aydin (2013). Fig. 2 shows a good agreement in streamlines and isotherms of present study with published results.

4. RESULTS AND DISCUSSIONS

The iso-surfaces of temperature for different Rayleigh number values are shown in Fig. 3. For low values of Rayleigh number, the flow is weak due to quasi-conduction dominant heat transfer regime and air is nearly at rest. The isotherms present an almost vertical stratification near the left adiabatic wall and an inclined stratification near the cooled right side. It is obvious that these iso-surfaces are always orthogonal the adiabatic walls. By increasing Rayleigh number, heated air near the inserted heater is increasingly driven due to buoyancy forces making a plumelike temperature distribution formed from the heated block to the inclined wall due to convection regime of heat transfer. As it can be seen from the figure, Rayleigh number is an effective parameter on flow strength and a strong plumelike flow is observed near the left adiabatic wall with the increasing of this parameter.

Trajectories of particles for different Rayleigh number values are illustrated in Fig. 4. It is noted that Prandtl number is fixed at Pr = 0.71 for whole work and Rayleigh number is changed from 10^3 to 10^5. It can be seen from the figure that, for low values of Ra, three vortices are formed because heated air moves up from the heater and impinges to the cold inclined wall. For Ra = 10^3, a vortex is formed between left side of the heater and insulated vertical wall of triangular enclosure which rotates in counterclockwise direction.

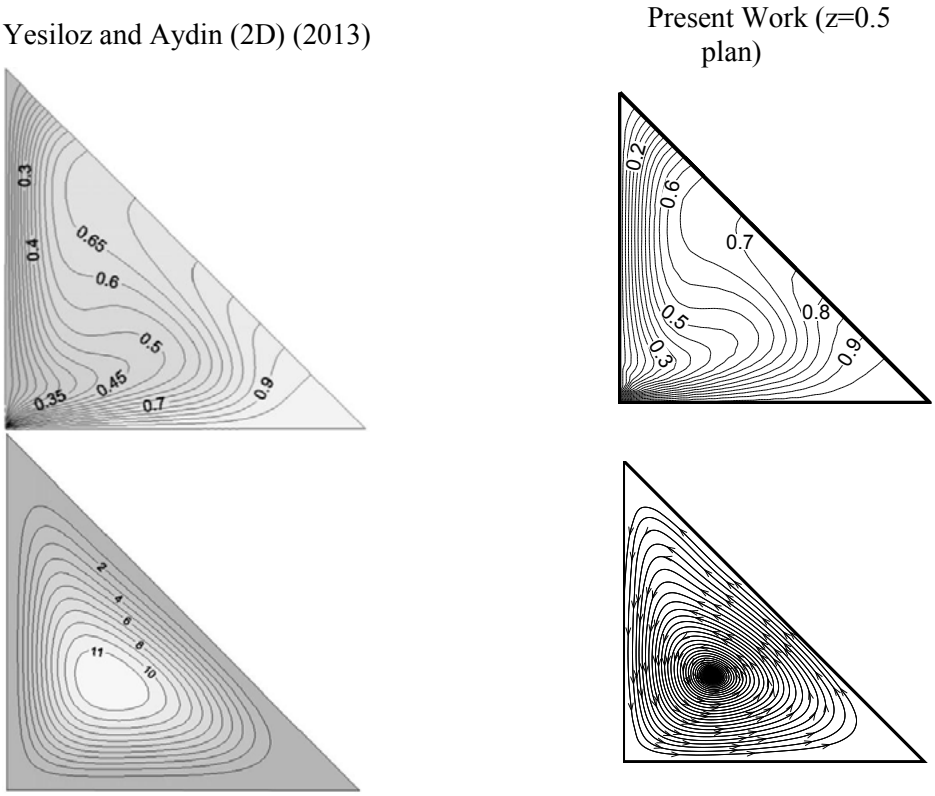

Fig. 2: Comparison with results of Yesiloz and Aydin (2013)

for Ra = 10^5 and Pr = 0.71

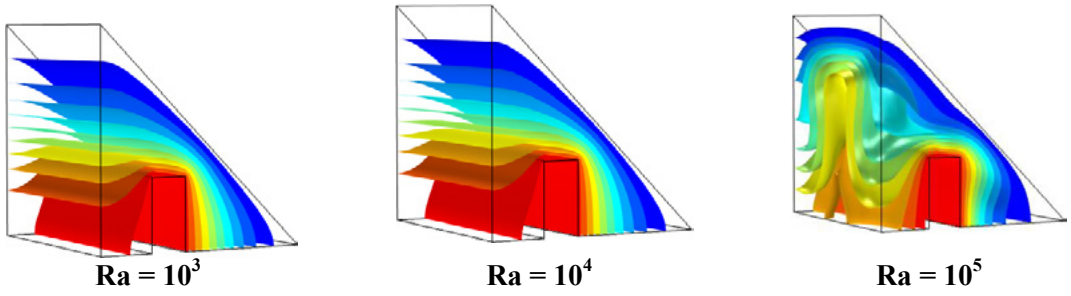

Fig. 3: Iso-surfaces of temperature for different Rayleigh number values

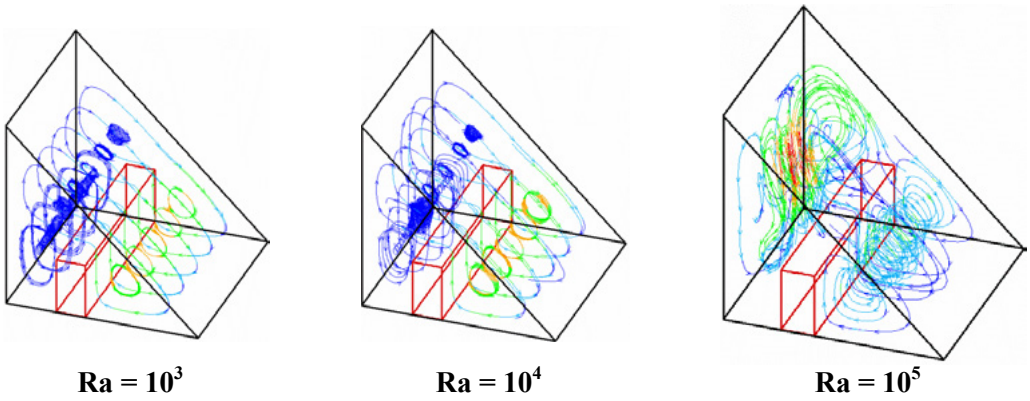

Fig. 4: Particles trajectory for different Rayleigh number values

Other two cells are obtained on the top of heater and right corner of the triangle enclosure. These are very similar for Ra =10^3 and Ra =10^4 due to quasi-conductive regime. Both top and right vortices rotate in clockwise direction due to rising fluid from heater to inclined wall. It rises and replaces with cooled fluid. The eye of vortices becomes almost in the same place with the increasing of Rayleigh number.

Trajectories of particles are more packed at the right side of the heater. It means that the flow moves faster as natural convection is intensified. As Rayleigh number increases (Ra = 10^5), velocity of fluid at the top of heater also increases due to increasing of effects of convection heat transfer regime. Increasing of Rayleigh number causes a denser clustering of temperature iso-surfaces and the three-dimensional character of the flow is more pronounced.

It is noticed that the rate of heat transfer inside the enclosure is measured in term of the overall Nusselt number. Therefore, fig. 5 shows the variation of the average Nusselt number, which characterizes the heat transfer from the inserted heater towards the vicinity of the enclosure, with the Rayleigh number. It is obvious that for low values of Ra and when the conduction is the dominant mode of heat transfer, this variation is insignificant. However, for $Ra \geq 10^4$ heat removal from the inserted heater increases by means of increasing Rayleigh number and the maximum rate is obtained for the highest Ra as expected. Indeed, by increasing Rayleigh number to 10^5, the fluid flow intensifies and the thermal energy transport increases due to the enhancement of convection heat transfer.

To achieve a maximum heat transfer rate between the inserted heater and the cooling air, it is essential to carry out an entropy generation analysis to investigate the two sources of irreversibilities that are responsible for heat losses. These irreversibilities are mainly due to heat transfer and fluid friction. Therefore, entropy generation due to heat transfer, the entropy generation due to friction and the total entropy generation as function of Rayleigh number are shown in fig. 6 for an irreversibility coefficient $\varphi = 10^{-5}$.

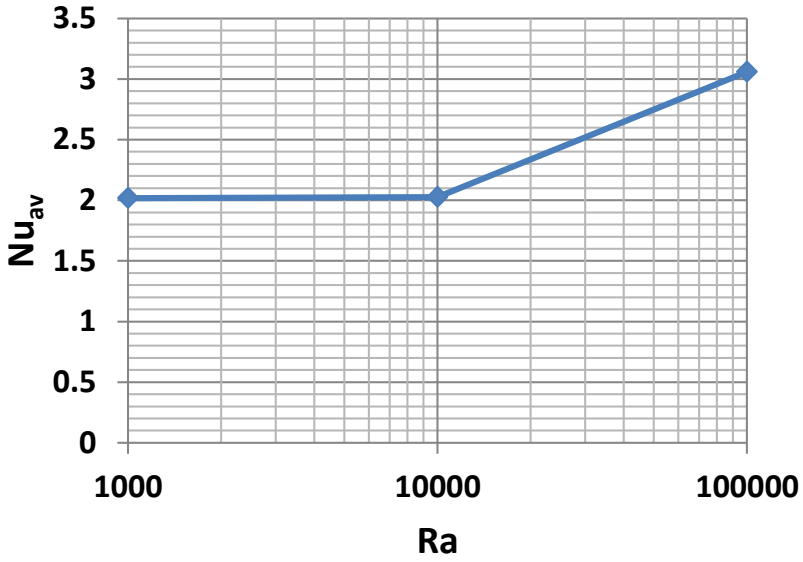

Fig. 5: Variation of Mean Nusselt number on cold wall with Rayleigh number

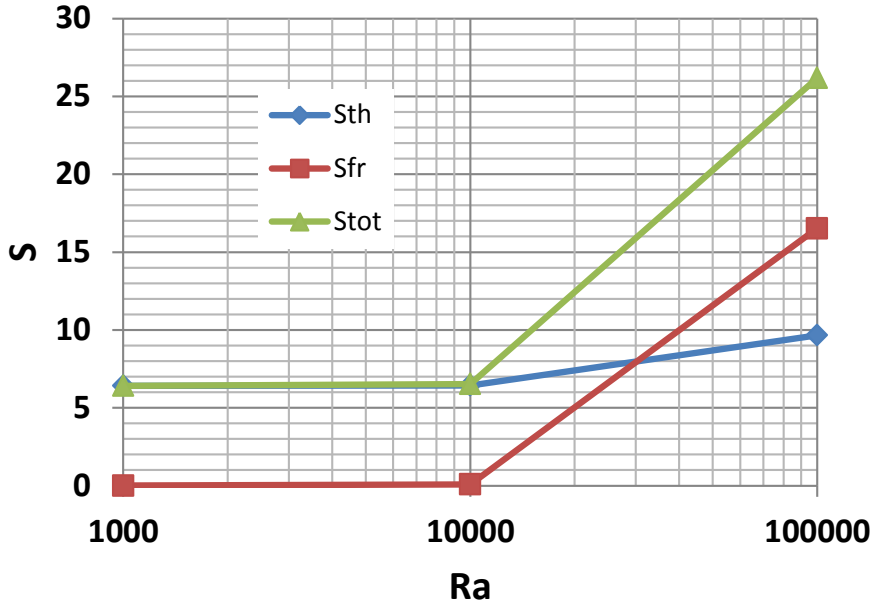

Fig. 6: Variations of entropy generations with Rayleigh number

For $Ra \leq 10^4$, entropy generation due to viscous irreversibility is less significant in deciding the total entropy generation, which is sum of entropy generations due to heat transfer and friction. Moreover, it can be observed that the entropy generation due to heat transfer and total entropy generation are equal which gives a clue that entropy due to heat transfer outweighs that due to fluid friction. However, an increasing of Ra ($Ra \geq 3*10^4$), fluid friction becomes the dominant cause of irreversibility and entropy generation due to viscous effects outweighs that due to heat transfer.

In order to better compare the magnitude of the two sources of irreversibilities, Fig. 7 illustrates the variation of Bejan number, which is the ratio of the heat transfer irreversibility to the total irreversibility. Indeed, the value of Be ranges from 0 to 1. Accordingly, Be = 0 and Be = 1 are two limiting cases indicating that the irreversibility is dominated by fluid friction and heat transfer, respectively. As shown from the figure, the highest value of Bejan number (almost 1) is obtained for the lowest Rayleigh number value (Ra = 10^3). It means that entropy generation due to fluid friction becomes insignificant and it is clear that irreversibility from heat transfer has dominant influence on resultant total entropy generation.

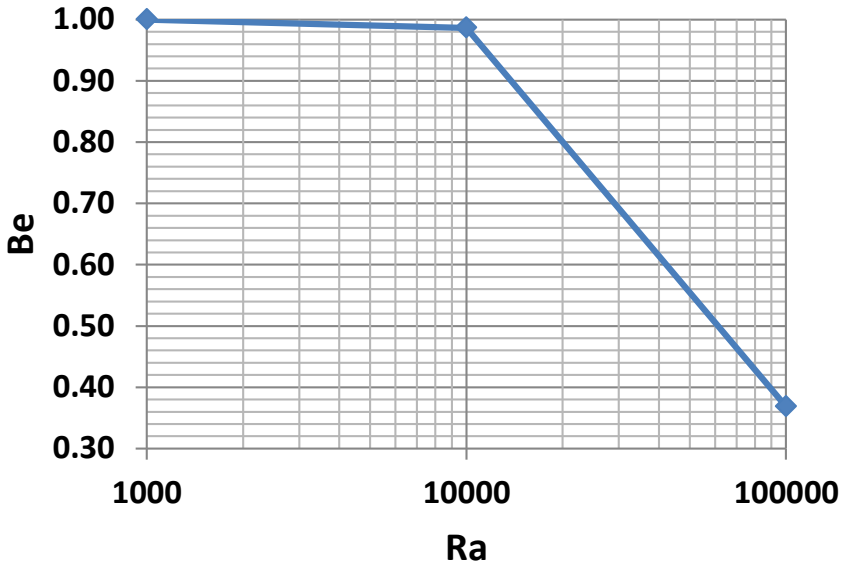

Fig. 7: Bejan number as function of Rayleigh number

5. CONCLUSIONS

Three-dimensional numerical investigation has been carried out to simulate natural convection and entropy generation in an air filled triangular cavity with inserted isothermal heater at the bottom wall. The analyzed cavity is cooled on its inclined wall while remaining walls are assumed to be insulated. Results are presented for different Rayleigh number values which is the main parameter of the study. In view of the obtained results, following findings may be summarized:

- For lower values of Rayleigh number, conduction is the primary mode of heat transfer and the flow strength is very low due to poor convective heat transfer.
- Flow strength increases with increasing of Rayleigh number and a strong convective current is noticeable along the inserted heater where cold air is heated.

- The flow structure and temperature distribution are sensitive to the value of Rayleigh number.
- Heat transfer is very weak at the left and top side of the heater when it is compared with the right side of the heater.
- Irreversibilities are mainly due to heat transfer at low Rayleigh number values and entropy generation due to fluid friction becomes more significant at high values.

Further study may include the effect parameters such as, heater height, heater width, heater location center and aspect ratio of triangular enclosure on heat transfer and fluid flow.

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NOMENCLATURE

g	gravitational acceleration [m/s^2]
k	thermal conductivity [W/m.K]
L	collector width
$\vec{n}$	unit vector normal to the wall
N_s	local generated entropy
Nu	Nusselt number
Pr	Prandtl number
Ra	Rayleigh number
$\vec{q}'$	heat flux vector
S'$_{gen}$	generated entropy
t	dimensionless time ($t'.\alpha / L^2$)
T	dimensionless temperature [$(T'-T'_c)/(T'_h-T'_c)$]
T'_c	cold temperature [K]
T'_h	hot temperature [K]
$\vec{V}$	dimensionless velocity vector ($=\vec{V}'.L/\alpha$)
x, y, z	dimensionless Cartesian coordinates (x'/L , y'/L , z'/L)

Greek symbols

α	thermal diffusivity [m^2 /s]
β	thermal expansion coefficient [1/K]

ρ	density [kg/m^3]
μ	dynamic viscosity [kg./m.s]
ν	kinematic viscosity [m^2/s]
φ	irreversibility coefficient
ϕ'	dissipation function
$\vec{\psi}$	dimensionless vector potential ($\vec{\psi}'/\alpha$)
$\vec{\omega}$	dimensionless vorticity ($\vec{\omega}'.\alpha/L^2$)
ΔT	dimensionless temperature difference

Subscripts

x, y, z	Cartesian coordinates
Th	thermal
Fr	friction
Tot	Total
h	Hot
c	Cold
av	average

Superscript

'	dimensional variable

On Regression Models for Discrete Difference Distributions

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ABSTRACT

We proposed five different regression models for discrete dependent variables that take both positive and negative values using the Skellam, skew Laplace, trinomial difference, and extended binomial distributions. We applied these models to data from England Premier League and compared their performances.

Keywords: Generalized Linear Model; Regression model; Skellam distribution; Skew Laplace distribution; Trinomial Difference distribution; Extended Binomial distribution.

1. INTRODUCTION

Count regression models as Binary, Poisson and negative binomial regression models are widely used to model count variables that take values in the set of nonnegative integers. Nelder and Wedderburn (1972) showed that these models form a subset of the general class of generalized linear models (GLM). The book of McCullagh and Nelder (1989) is one of the standard books for these models. Hilbe (2011) presented the negative binomial model in detail. Extension of these models to vector of parameters set up can be found in the book of Yee (2015). Nowadays, most packages provide programs that analyze data using GLM. For these models, it is assumed that a function of the mean is linked linearly to the set of explanatory variables and the distribution of the dependent variable is a member of the exponential family distributions. Recently, the difference between two nonnegative integer random variables has attracted the attention of many researchers. The most popular distribution on Z is the Skellam distribution defined by taking the difference of two Poisson random variables. Karlis and Ntzoufras (2006) used the Skellam and the zero inflated Skellam distributions to model an application from dental epidemiology. Karlis and Ntzoufras (2009) also used the Skellam distribution to model the difference of the number of goals in football games. Alzaid and Omair (2010) have used the Skellam distribution for Stock market and hospital occupancy in a nursery intensive care unit. Inusah and Kozubowski (2006) studied discrete skew Laplace distribution (DL). Ong ***et al.*** (2008) defined the difference between two discrete random variables from the Panjer family. Alzaid and Omair (2012) introduced the extended binomial distribution as an extension of the binomial distribution to allow for negative values. Omair ***et al.*** (2016) defined the trinomial difference distribution and used motorcycle accident data for fitting this distribution. Very limited research has considered the regression models using distribution on Z. Karlis and Ntzoufras (2009) applied the Bayesian methodology for the Skellam's distribution for the goal difference using covariates.

This paper is concerned with developing regression models for such distributions. Our approach mimics that of the GLM. The paper is organized as follows: In the rest of this section the basic assumptions of the GLM are given. We developed models for Skellam, skew Laplace, trinomial difference and extended binomial

distributions in Section 2. In Section 3, we applied models of Section 2 to a set of data drawn from the English Premier League.

The GLM mainly model one parameter (the mean) of the underlying distribution which is a member of the exponential family. The proposed models in this paper provide greater flexibility.

Nelder and Wederburn (1972) considered a generalized linear model (GLM) in a unified way.

Let $Y_1, Y_2, ..., Y_n$ be a set of independent random variables. The basic assumptions of GLM are as follows:

1) The distribution of each Y_i has the conical exponential family form which depends on parameter θ_i (where θ_i is different) with:

$$f(y_i, \theta_i) = exp[y_i b(\theta_i) + c(\theta_i) + d(y_i)] \quad (1)$$

where b, c and d are known functions.

2) All Y_i 's have the same distributions and the joint probability density function of $Y_1, Y_2, ..., Y_n$ is

$$f(y_1, ..., y_n; \theta_1, ..., \theta_n) = \prod_{i=1}^{n} exp[y_i b(\theta_i) + c(\theta_i) + d(y_i)] \quad (2)$$
$$= exp\left[\sum_{i=1}^{n} y_i b(\theta_i) + \sum_{i=1}^{n} c(\theta_i) + \sum_{i=1}^{n} d(y_i)\right].$$

3) If $\mu_i = E(Y_i)$ which is the function of θ_i then it is assumed that there is a monotonic differential function say g such that

$$g(\mu_i) = \mathbf{x}_i^T \boldsymbol{\beta}, \quad (3)$$

g is named the link function where the vector $\mathbf{x}_i^T = (1\, x_{i1} \ldots x_{ip-1})$ be a $1 \times p$ vector of explanatory variables corresponding to the observation i and $\boldsymbol{\beta} = (\beta_0 \ldots \beta_{p-1})^T$ is $p \times 1$ vector of the parameters. The vector $\mathbf{x}_i^T$ is the ith row of the design matrix $\mathbf{X}$ which is defined as

$$\mathbf{X} = \begin{bmatrix} \mathbf{x_1^T} \\ \vdots \\ \mathbf{x_n^T} \end{bmatrix} = \begin{bmatrix} 1 & x_{11} & \ldots & x_{1p-1} \\ & \vdots & & \vdots \\ 1 & x_{n1} & \ldots & x_{np-1} \end{bmatrix}$$

2. REGRESSION MODEL FOR DISTRIBUTIONS ON Z

Unlike the count model on the set of non-negative integers, the mean of count difference variables can take positive and negative values and hence can also be modeled linearly using identity link. Let $z_1, z_2, \ldots, z_n$ be a set of random variables and let $\mathbf{x}_i^T = (1\, x_{i1} \ldots x_{ip-1})$ be a $1 \times p$ vector of explanatory variables.

2.1 Skellam Model

Unlike the Poisson distribution, the Skellam distribution has two parameters. These two parameters are linked to the mean and the variance as in the following equations. Let z~Skellam (θ_1, θ_2) then

$$P(Z=z) = e^{-\theta_1-\theta_2}\left(\frac{\theta_1}{\theta_2}\right)^{\frac{z}{2}} I_z\left(2\sqrt{\theta_1\theta_2}\right), \quad z=0,\pm1,\pm2,\ldots \qquad (4)$$

where $I_z(x)$ is the modified Bessel function. The mean and the variance are $\mu = \theta_1 - \theta_2$ and $\sigma^2 = \theta_1 + \theta_2$.

$$\mathrm{P(Z=z)} = \exp(-\sigma^2)\left(\frac{\sigma^2+\mu}{\sigma^2-\mu}\right)^{\frac{z}{2}} \mathrm{I_z}\left(\sqrt{\sigma^4-\mu^2}\right), \; z=0, \pm1, \pm2,\ldots \qquad (5)$$

Therefore, we can either model the mean when the variance is not affected by the explanatory variables or model the two parameters to catch the effect of the explanatory variables on the variance.

1) Modeling the Mean

To model the mean, it is better to use the probability function (5). As in the GLM, we assume there is a link function that connects the mean with the parameter as in

$$g(\mu_i) = \mathbf{x}_i^T \boldsymbol{\beta} = \eta_i . \qquad (6)$$

The likelihood function of this model is

$$L(\mathbf{z}, \mu, \sigma^2) = \prod_{i=1}^{n} \exp(-\sigma^2)\left(\frac{\sigma^2+\mu_i}{\sigma^2-\mu_i}\right)^{\frac{z_i}{2}} I_{z_i}\left(\sqrt{\sigma^4-\mu_i^2}\right), \quad z_i = 0,\pm1,\pm2,\ldots, \; i=1,2,\ldots,n.$$

The score functions are given by

$$U_k = \frac{\partial logL}{\partial \boldsymbol{\beta}_k} = \frac{\partial logL}{\partial \mu_i}\frac{\partial \mu_i}{\partial \eta_i}\frac{\partial \eta_i}{\partial \boldsymbol{\beta}_k} \quad i=1,2,..,n, \;\; k=0,1,...,p-1 \qquad (7)$$

To find the estimate of the regression parameters $\boldsymbol{\beta}$ and σ, we solve the equations

$$U_k = \frac{\partial l}{\partial \boldsymbol{\beta}_k} = \sum_{i=1}^{n} \left(\frac{z_i}{\hat{\sigma}^2 + \hat{\mu}_i} - \frac{\hat{\mu}_i}{\sqrt{\hat{\sigma}^4 - \hat{\mu}_i^2}} R_{z_i}\left(\sqrt{\hat{\sigma}^4 - \hat{\mu}_i^2}\right) \right) \mathbf{x}_i^T = 0 \tag{8}$$

$$\frac{\partial l}{\partial \sigma^2} = \sum_{i=1}^{n} \left(-1 + \frac{z_i}{\hat{\sigma}^2 + \hat{\mu}_i} + \frac{\hat{\sigma}^2}{\sqrt{\hat{\sigma}^4 - \hat{\mu}_i^2}} R_{z_i}\left(\sqrt{\hat{\sigma}^4 - \hat{\mu}_i^2}\right) \right) = 0, \tag{9}$$

where $R_z(x) = \dfrac{I_{z+1}(x)}{I_z(x)}$.

For this model, two link functions are of interest, namely the identity

$$g_1(\mu_i) = \mu_i, \tag{10}$$

and the log function

$$g_2(\mu_i) = log\, \mu_i. \tag{11}$$

A possible interpretation of the identity model (10) is as follows

$$\begin{aligned} E(Y_i) &= \mathbf{x}^T \boldsymbol{\beta} \\ Y_i &= Z_i + \varepsilon_i, \end{aligned}$$

where $Z_i(\mathbf{x}^T\boldsymbol{\beta}) \sim Skellam(\mathbf{x}^T\boldsymbol{\beta}, \sigma_1^2)$ is independent of $\varepsilon_i \sim Skellam(0, \sigma_2^2)$ and $\sigma_1^2 + \sigma_2^2 = \sigma^2$.

2) Modeling the parameters

For this model, we considered the standard Skellam probability mass function (4). We assumed here that the parameters θ_1 and θ_2 are linked with the explanatory variables by

$\theta_{1i} = \exp(\mathbf{x}_i^T \boldsymbol{\beta}_1)$ and $\theta_{2i} = \exp(\mathbf{x}_i^T \boldsymbol{\beta}_2)$

Here, we assumed the independence of the parameters to be

$$\boldsymbol{\beta_1} = \begin{bmatrix} \beta_{10} \\ \vdots \\ \beta_{1p-1} \end{bmatrix} \text{ and } \boldsymbol{\beta_2} = \begin{bmatrix} \beta_{20} \\ \vdots \\ \beta_{2p-1} \end{bmatrix}$$

The corresponding likelihood function for (4) is given by

$$L(\mathbf{z}, \theta_{1i}, \theta_{2i}) = \prod_{i=1}^{n} \exp(-\theta_{1i} - \theta_{2i}) \left(\frac{\theta_{1i}}{\theta_{2i}} \right)^{\frac{z_i}{2}} I_{z_i}\left(2\sqrt{\theta_{1i}\theta_{2i}}\right). \tag{12}$$

Hence, the score functions are given by

$$U_{lk} = \frac{\partial l}{\partial \beta_{lk}} = \sum_{i=1}^{n} \frac{\partial l_i}{\partial \theta_{ki}} \frac{\partial \theta_{ki}}{\partial \beta_{lk}}, \; i = 1,2,...,n, \; k = 0,1,...,p-1, \; l = 1,2. \tag{13}$$

The maximum likelihood estimator of the regression parameter $\boldsymbol{\beta}_l$ is obtained by solving the following nonlinear equations:

$$\frac{\partial l}{\partial \beta_{1k}} = \sum_{i=1}^{n}\left(-\hat{\theta}_{1i} + z_i + \sqrt{\hat{\theta}_{1i}\hat{\theta}_{2i}}R_{z_i}\left(2\sqrt{\hat{\theta}_{1i}\hat{\theta}_{2i}}\right)\right)x_{ik} = 0 \tag{14}$$

$$\frac{\partial l}{\partial \beta_{2k}} = \sum_{i=1}^{n}\left(-\hat{\theta}_{2i} + z_i + \sqrt{\hat{\theta}_{1i}\hat{\theta}_{2i}}R_{z_i}\left(2\sqrt{\hat{\theta}_{1i}\hat{\theta}_{2i}}\right)\right)x_{ik} = 0, \tag{15}$$

where $\theta_{li} = e^{\mathbf{x}_i^T\boldsymbol{\beta}_l}$, $l = 1,2$ and $k = 0,1,...,p-1$.

Hypothesis test and confidence interval can be based on the fact the maximum likelihood estimator $\hat{\Theta} = (\hat{\theta}_1, \hat{\theta}_2)$ is asymptotically normally distributed $N(\Theta, I^{-1}(\Theta))$ where

$$I(\Theta) = \begin{pmatrix} I_{11} & I_{12} \\ I_{21} & I_{22} \end{pmatrix}$$

is a 2p × 2p matrix, with

$$I_{ll} = \begin{bmatrix} \frac{\partial^2 l}{\partial\beta_{l0}\partial\beta_{l0}} & \frac{\partial^2 l}{\partial\beta_{l0}\partial\beta_{l1}} & \cdots & \frac{\partial^2 l}{\partial\beta_{l0}\partial\beta_{lp-1}} \\ \vdots & & & \vdots \\ \frac{\partial^2 l}{\partial\beta_{lp-1}\partial\beta_{l0}} & \frac{\partial^2 l}{\partial\beta_{lp-1}\partial\beta_{l1}} & \cdots & \frac{\partial^2 l}{\partial\beta_{lp-1}\partial\beta_{lp-1}} \end{bmatrix}, l = 1,2, \tag{16}$$

and

$$I_{12} = I_{21} = \begin{bmatrix} \frac{\partial^2 l}{\partial\beta_{10}\partial\beta_{20}} & \frac{\partial^2 l}{\partial\beta_{10}\partial\beta_{21}} & \cdots & \frac{\partial^2 l}{\partial\beta_{10}\partial\beta_{2p-1}} \\ \vdots & & & \vdots \\ \frac{\partial^2 l}{\partial\beta_{1p-1}\partial\beta_{20}} & \frac{\partial^2 l}{\partial\beta_{1p-1}\partial\beta_{21}} & \cdots & \frac{\partial^2 l}{\partial\beta_{1p-1}\partial\beta_{2p-1}} \end{bmatrix}, \tag{17}$$

are p × p matrices.

For the present model, we have

$$I_{11}=-\frac{\partial^2 l}{\partial\beta_{1k}\beta_{1j}}=-\sum_{i=1}^{n}\Big\{-\theta_{1i}+\sqrt{\theta_{1i}\theta_{2i}}R_{z_i}(\sqrt{\theta_{1i}\theta_{2i}})+\theta_{1i}\theta_{2i}R_{z_i+1}(\sqrt{\theta_{1i}\theta_{2i}})$$
$$\times R_{z_i}(\sqrt{\theta_{1i}\theta_{2i}})-\theta_{1i}\theta_{2i}\left(R_{z_i}(\sqrt{\theta_{1i}\theta_{2i}})\right)^2\Big\}\times x_{ik}x_{ij}. \quad (18)$$

$$I_{22}=-\frac{\partial^2 l}{\partial\beta_{2k}\beta_{2j}}=-\sum_{i=1}^{n}\Big\{-\theta_{2i}+\sqrt{\theta_{1i}\theta_{2i}}R_{z_i}(\sqrt{\theta_{1i}\theta_{2i}})+\theta_{1i}\theta_{2i}R_{z_i+1}(\sqrt{\theta_{1i}\theta_{2i}})$$
$$\times R_{z_i}(\sqrt{\theta_{1i}\theta_{2i}})-\theta_{1i}\theta_{2i}\left(R_{z_i}(\sqrt{\theta_{1i}\theta_{2i}})\right)^2\Big\}\times x_{ik}x_{ij}. \quad (19)$$

$$I_{12}=I_{21}=-\frac{\partial^2 l}{\partial\beta_{1k}\beta_{2j}}=-\sum_{i=1}^{n}\Big\{\sqrt{\theta_{1i}\theta_{2i}}R_{z_i}(\sqrt{\theta_{1i}\theta_{2i}})+\theta_{1i}\theta_{2i}R_{z_i+1}(\sqrt{\theta_{1i}\theta_{2i}})$$
$$\times R_{z_i}(\sqrt{\theta_{1i}\theta_{2i}})-\theta_{1i}\theta_{2i}\left(R_{z_i}(\sqrt{\theta_{1i}\theta_{2i}})\right)^2\Big\}\times x_{ik}x_{ij}, \quad (20)$$

where k, j=0,1,...,p-1.

*2.2 **Skew Laplace Model***

Let z~skew Laplace (p_1, p_2) then the probability mass function is

$$P(Z=z)=\frac{(1-p_1)(1-p_2)}{1-p_1p_2}\begin{cases}p_1^{z} & z=0,1,2,3,...\\ p_2^{-z} & z=0,-1,-2,-3,...,\end{cases} \quad (21)$$

For a skew Laplace model, the ith observation can be written as

$$f(z_i\mid p_{1i},p_{2i})=P(Z=z_i)=\frac{(1-p_{1i})(1-p_{2i})}{1-p_{1i}p_{2i}}p_{1i}^{\frac{|z_i|+z_i}{2}}p_{2i}^{\frac{|z_i|-z_i}{2}},\quad i=1,2,...,n \quad (22)$$

where $0<p_{ki}<1$, for k=1, 2 and i=1,2,...,n, and the following link functions:

$$p_{li}=\frac{e^{\mathbf{x}_i^T\boldsymbol{\beta}_l}}{1+e^{\mathbf{x}_i^T\boldsymbol{\beta}_l}},\ l=1,2.$$

The corresponding likelihood function is

$$L(\mathbf{z},p_{1i},p_{2i})=\prod_{i=1}^{n}\frac{(1-p_{1i})(1-p_{2i})}{1-p_{1i}p_{2i}}p_{1i}^{\frac{|z_i|+z_i}{2}}p_{2i}^{\frac{|z_i|-z_i}{2}}. \quad (23)$$

To obtain the maximum likelihood estimator of $\boldsymbol{\beta}_l$ we solve these following equations:

$$\frac{\partial l}{\partial\beta_{1k}}=\sum_{i=1}^{n}\Big(\frac{\hat{p}_{1i}\hat{p}_{2i}(1-\hat{p}_{1i})}{1-\hat{p}_{1i}\hat{p}_{2i}}-\hat{p}_{1i}+\frac{|z_i|+z_i}{2}(1-\hat{p}_{1i})\Big)x_{ik}=0 \quad (24)$$

$$\frac{\partial l}{\partial\beta_{2k}}=\sum_{i=1}^{n}\Big(\frac{\hat{p}_{1i}\hat{p}_{2i}(1-\hat{p}_{2i})}{1-\hat{p}_{1i}\hat{p}_{2i}}-\hat{p}_{2i}+\frac{|z_i|-z_i}{2}(1-\hat{p}_{2i})\Big)x_{ik}=0 \quad (25)$$

where k=0,1,...,p-1.

Hence, the information matrix is given by

$$I_{11} = -\frac{\partial^2 l}{\partial\beta_{1k}\beta_{1j}} = -\sum_{i=1}^{n}\Big(\frac{p_{1i}p_{2i}(1-p_{1i})(1-2p_{1i}+p_{1i}^2p_{2i})}{(1-p_{1i}p_{2i})^2} - \Big(1+\frac{|z_i|+z_i}{2}\Big)p_{1i}(1-p_{1i})\Big)x_{ik}x_{ij} \quad (26)$$

$$I_{22} = -\frac{\partial^2 l}{\partial\beta_{2k}\beta_{2j}} = -\sum_{i=1}^{n}\Big(\frac{p_{1i}p_{2i}(1-p_{2i})(1-2p_{2i}+p_{2i}^2p_{1i})}{(1-p_{1i}p_{2i})^2} - \Big(1+\frac{|z_i|-z_i}{2}\Big)p_{2i}(1-p_{2i})\Big)x_{ik}x_{ij} \quad (27)$$

$$I_{12} = I_{21} = -\frac{\partial^2 l}{\partial\beta_{1k}\beta_{2j}} = -\sum_{i=1}^{n}\Big(\frac{p_{1i}p_{2i}(1-p_{1i})(1-p_{2i})}{(1-p_{1i}p_{2i})^2}\Big)x_{ik}x_{ij} \quad (28)$$

2.3 ***Trinomial Difference Model***

Let z~Trinomial difference (n, ⍰α,γ) then the probability distribution function is

$$P(Z=z) = \sum_{j=max(0,-z)}^{\left[\frac{n-z}{2}\right]}\binom{n}{z+j,j}\alpha^{z+j}\gamma^{j}(1-\alpha-\gamma)^{n-z-2j} \quad z=0,\pm1,\pm2,...,\pm n \quad (29)$$

where $n \in Z, 0 \le \alpha,\gamma \le 1$ and $\alpha+\gamma<1$. The ith observation is

$$f(z_i|\alpha_i,\gamma_i) = P(Z=z_i) = \sum_{j=max(0,-z_i)}^{\left[\frac{n-z_i}{2}\right]}\binom{n}{z_i+j,j}\alpha_i^{z_i+j}\gamma_i^{j}(1-\alpha_i-\gamma_i)^{n-z_i-2j}, \quad (30)$$

where $z_i = 0,\pm1,\pm2,...,\pm n$ and i=1,2,...,m with the following link functions:

$$\alpha_i = \frac{\exp(\mathbf{x}_i^T\boldsymbol{\beta}_1)}{1+\exp(\mathbf{x}_i^T\boldsymbol{\beta}_1)+\exp(\mathbf{x}_i^T\boldsymbol{\beta}_2)} \quad \text{and} \quad \gamma_i = \frac{\exp(\mathbf{x}_i^T\boldsymbol{\beta}_2)}{1+\exp(\mathbf{x}_i^T\boldsymbol{\beta}_1)+\exp(\mathbf{x}_i^T\boldsymbol{\beta}_2)}$$

The likelihood function for this model is given by

$$L(\mathbf{z},\alpha_i,\gamma_i) = \prod_{i=1}^{m}\sum_{j=max(0,-z_i)}^{\left[\frac{n-z_i}{2}\right]}\binom{n}{z_i+j,j}\alpha_i^{z_i+j}\gamma_i^{j}(1-\alpha_i-\gamma_i)^{n-z_i-2j} \quad (31)$$

The maximum likelihood estimator of $\boldsymbol{\beta}_l$ is given by solving these two equations:

$$\frac{\partial l}{\partial \boldsymbol{\beta}_{1k}} = \sum_{i=1}^{m} \frac{\sum_{j=max(0,-z_i)}^{\left[\frac{n-z_i}{2}\right]} \binom{n}{z_i+j,j} \hat{\alpha}_i^{z_i+j} \hat{\gamma}_i^{j} (1-\hat{\alpha}_i-\hat{\gamma}_i)^{n-z_i-2j} \left[z_i + j - n\hat{\alpha}_i\right]}{\sum_{j=max(0,-z_i)}^{\left[\frac{n-z_i}{2}\right]} \binom{n}{z_i+j,j} \hat{\alpha}_i^{z_i+j} \hat{\gamma}_i^{j} (1-\hat{\alpha}_i-\hat{\gamma}_i)^{n-z_i-2j}} \times x_{ik} = 0 \quad (32)$$

$$\frac{\partial l}{\partial \boldsymbol{\beta}_{2k}} = \sum_{i=1}^{m} \frac{\sum_{j=max(0,-z_i)}^{\left[\frac{n-z_i}{2}\right]} \binom{n}{z_i+j,j} \hat{\alpha}_i^{z_i+j} \hat{\gamma}_i^{j} (1-\hat{\alpha}_i-\hat{\gamma}_i)^{n-z_i-2j} \left[j - n\hat{\gamma}_i\right]}{\sum_{j=max(0,-z_i)}^{\left[\frac{n-z_i}{2}\right]} \binom{n}{z_i+j,j} \hat{\alpha}_i^{z_i+j} \hat{\gamma}_i^{j} (1-\hat{\alpha}_i-\hat{\gamma}_i)^{n-z_i-2j}} \times x_{ik} = 0 \quad (33)$$

where k=0, 1,..., p-1.

Thus, the information matrix for this model is given by

$$I_{11} = -\frac{\partial^2 l}{\partial \boldsymbol{\beta}_{1k} \partial \boldsymbol{\beta}_{1j}} = \sum_{i=1}^{m} \frac{\sum_{j=max(0,-z_i)}^{\left[\frac{n-z_i}{2}\right]} \binom{n}{z_i+j,j} n\alpha_i^{z_i+j+1} \gamma_i^{j} (1-\alpha_i)(1-\alpha_i-\gamma_i)^{n-z_i-2j}}{\sum_{j=max(0,-z_i)}^{\left[\frac{n-z_i}{2}\right]} \binom{n}{z_i+j,j} \alpha_i^{z_i+j} \gamma_i^{j} (1-\alpha_i-\gamma_i)^{n-z_i-2j}} \times x_{ik} x_{ij}, \quad (34)$$

$$I_{22} = -\frac{\partial^2 l}{\partial \boldsymbol{\beta}_{2k} \partial \boldsymbol{\beta}_{2j}} = \sum_{i=1}^{m} \frac{\sum_{j=max(0,-z_i)}^{\left[\frac{n-z_i}{2}\right]} \binom{n}{z_i+j,j} n\alpha_i^{z_i+j} \gamma_i^{j+1} (1-\gamma_i)(1-\alpha_i-\gamma_i)^{n-z_i-2j}}{\sum_{j=max(0,-z_i)}^{\left[\frac{n-z_i}{2}\right]} \binom{n}{z_i+j,j} \alpha_i^{z_i+j} \gamma_i^{j} (1-\alpha_i-\gamma_i)^{n-z_i-2j}} \times x_{ik} x_{ij}, \quad (35)$$

$$I_{12} = I_{21} = -\frac{\partial^2 l}{\partial \boldsymbol{\beta}_{1k} \partial \boldsymbol{\beta}_{2j}} = -\sum_{i=1}^{m} \frac{\sum_{j=max(0,-z_i)}^{\left[\frac{n-z_i}{2}\right]} \binom{n}{z_i+j,j} n\alpha_i^{z_i+j+1} \gamma_i^{j+1} (1-\alpha_i-\gamma_i)^{n-z_i-2j}}{\sum_{j=max(0,-z_i)}^{\left[\frac{n-z_i}{2}\right]} \binom{n}{z_i+j,j} \alpha_i^{z_i+j} \gamma_i^{j} (1-\alpha_i-\gamma_i)^{n-z_i-2j}} \times x_{ik} x_{ij}, \quad (36)$$

k, j=0,1,...,p-1.

*2.4 **Extended Binomial Model***

Let z~extended binomial (w, *p*, θ) then the probability distribution function is

$$P(Z=z)=\frac{p^z\, q^{w-z}\ {}_0\tilde{F}_1(;z+1;p^2\theta)\ {}_0\tilde{F}_1(;w-z;q^2\theta)}{{}_0\tilde{F}_1(;w+1;\theta)} \tag{37}$$

where

where $z=0,\pm1,\pm2,\ldots$.

The ith observation is

$$f(z_i|p_i\ \theta_i)=p(Z=z_i)$$
$$=\frac{p_i^{z_i}\, q_i^{w-z_i}\ {}_0\tilde{F}_1(;z_i+1;p_i^2\theta_i)\ {}_0\tilde{F}_1(;w-z_i;q_i^2\theta_i)}{{}_0\tilde{F}_1(;w+1;\theta_i)} \tag{38}$$

Where ${}_0\tilde{F}_1(;w;\theta)$ is the regularized generalized hypergeometric function and i=1, 2,...,n, with the following link functions:

$$p_i=\frac{\exp(\mathbf{x}_i^T\boldsymbol{\beta}_1)}{1+\exp(\mathbf{x}_i^T\boldsymbol{\beta}_1)} \qquad \text{and} \qquad \theta_i=\exp(\mathbf{x}_i^T\boldsymbol{\beta}_2).$$

The maximum likelihood estimator of $\boldsymbol{\beta}_l$ is given by

$$L(\mathbf{z},p_i,\theta_i)=\prod_{i=1}^{n}\frac{p_i^{z_i}\, q_i^{w-z_i}\ {}_0\tilde{F}_1(;z_i+1;p_i^2\theta_i)\ {}_0\tilde{F}_1(;w-z_i;q_i^2\theta_i)}{{}_0\tilde{F}_1(;w+1;\theta_i)} \tag{39}$$

To find the estimator of β_k we solve these non-linear equations:

$$\frac{\partial l}{\partial\beta_{1k}}=\sum_{i=1}^{n}\Big(z_i(1-\hat{p}_i)-(w-z_i)\hat{p}_i+2\hat{p}_i^2(1-\hat{p}_i)\hat{\theta}_i H_1(z_i+2,\hat{p}_i^2\hat{\theta}_i) \tag{40}$$
$$-2\hat{p}_i(1-\hat{p}_i)^2\hat{\theta}_i H_1(w-z_i+2,(1-\hat{p}_i)^2\hat{\theta}_i)\Big)x_{ik}=0$$
$$\frac{\partial l}{\partial\beta_{2k}}=\sum_{i=1}^{n}\Big(-\hat{\theta}_i H_1(w+2,\hat{\theta}_i)+\hat{p}_i^2\hat{\theta}_i H_1(z_i+2,\hat{p}_i^2\hat{\theta}_i) \tag{41}$$
$$+(1-\hat{p}_i)^2\hat{\theta}_i H_1(w-z_i+2,(1-\hat{p}_i)^2\hat{\theta}_i)\Big)x_{ik}=0.$$

where $H_k(u_1+1,u_2+1,\ldots,u_k+1,\theta)=\frac{{}_0\tilde{F}_k(u_1+1,u_2+1,\ldots,u_k+1;\theta)}{{}_0\tilde{F}_k(u_1,u_2,\ldots,u_k;\theta)}$.

For the present model, we have

$$
\begin{aligned}
I_{11} = -\frac{\partial^2 l}{\partial\beta_{1k}\,\beta_{1j}} = -\sum_{i=1}^{n}\Big(& 2p_i^2(1-p_i)(2-3p_i)\theta_i H_1(z_i+2, p_i^2\theta_i) + 4p_i^4(1-p_i)^2\theta_i^2 \\
& \times\Big(H_1(z_i+3, p_i^2\theta_i)H_1(z_i+2, p_i^2\theta_i) - (H_1(z_i+2, p_i^2\theta_i))^2\Big) \\
& - 2p_i(1-p_i)(1-4p_i+3p_i^2)\theta_i H_1(w-z_i+2, (1-p_i)^2\theta_i) - \\
& wp_i(1-p_i) + 4p_i^2(1-p_i)^4\theta_i^2\Big(H_1(w-z_i+3, (1-p_i)^2\theta_i)\times \\
& H_1(w-z_i+2, (1-p_i)^2\theta_i) - (H_1(w-z_i+2, (1-p_i)^2\theta_i))^2\Big)\Big)x_{ik}x_{ij}
\end{aligned}
\tag{42}
$$

$$
\begin{aligned}
I_{22} = -\frac{\partial^2 l}{\partial\beta_{2k}\,\partial\beta_{2j}} = -\sum_{i=1}^{n}\Big(& -\theta_i H_1(w+2, \theta_i) - \theta_i^2\Big(H_1(w+3, \theta_i)H_1(w+2, \theta_i) \\
& - \Big(H_1(w+2, \theta_i)\Big)^2\Big) + p_i^2\theta_i H_1(z_i+2, p_i^2\theta_i) + \theta_i^2 p_i^2 \\
& \times\Big(H_1(z_i+3, p_i^2\theta_i)H_1(z_i+2, p_i^2\theta_i) - \Big(H_1(z_i+2, p_i^2\theta_i)\Big)^2\Big) \\
& + (1-p_i)^2\theta_i H_1(w-z_i+2, +(1-p_i)^2\theta_i) + (1-p_i)^4 \\
& \times\theta_i^2\Big(H_1(w-z_i+3, +(1-p_i)^2\theta_i)H_1(w-z_i+2, +(1-p_i)^2\theta_i) \\
& - \Big(H_1(w-z_i+2, +(1-p_i)^2\theta_i)\Big)^2\Big)\Big)x_{ik}x_{ij}
\end{aligned}
\tag{43}
$$

$$
\begin{aligned}
I_{12} = I_{21} = -\frac{\partial^2 l}{\partial\beta_{1k}\,\partial\beta_{2j}} = -\sum_{i=1}^{n}\Big(& 2p_i^2(1-p_i)\theta_i H_1(z_i+2, p_i^2\theta_i) + 2p_i^4(1-p_i)\theta_i^2 \\
& \times\Big(H_1(z_i+3, p_i^2\theta_i)H_1(z_i+2, p_i^2\theta_i) - (H_1(z_i+2, p_i^2\theta_i))^2\Big) \\
& - 2p_i(1-p_i)^2\theta_i H_1(w-z_i+2, (1-p_i)^2\theta_i) - 2p_i(1-p_i)^4\theta_i^2 \\
& \times\Big(H_1(w-z_i+3, (1-p_i)^2\theta_i)H_1(w-z_i+2, (1-p_i)^2\theta_i) \\
& - (H_1(w-z_i+2, (1-p_i)^2\theta_i))^2\Big)\Big)x_{ik}x_{ij}.
\end{aligned}
\tag{44}
$$

The procedure NLMIXED in SAS software was used to fit these models.

3. APPLICATIONS

3.1 ***Application 1***

The data is obtained from the English Premier League for 2013-2014 seasons. Data were downloaded from http://uk.soccerway.com/. We fitted Skellam, skew Laplace, trinomial difference and the extended binomial models for the goal difference in 2013-2014 seasons. We specified the response variable Y as the goal deference (number of goals by the home team - number of goals by the away team). We used the goal difference (X_1), the total points for the home team (X_2) and the total points for the away team (X_3) in the similar game occurred the last year 2012-2013 as explanatory variables. Note that we eliminated the cases where there are no similar games in 2012-2013 and 2013-2014. We fitted all models, and then we eliminated the non-significant variables. Table 1 displays some descriptive statistics for response and explanatory variables.

Table 1. Descriptive Statistics

Variable	Sample size	Mean	Standard deviation	Minimum	Maximum	Skewness
Y	272	0.401	1.977	-5	7	0.24
X_1	272	0.105	1.739	-6	8	0.40
X_2	272	15.878	15.878	39	89	0.68
X_3	272	15.878	15.878	39	89	0.68

Table 2 displays the fitted models for all parameters. Table 3 shows the fitted models using only significant variables. Based on AIC, Table 2 indicates that the trinomial difference model provided a better fit than the other models. From Table 3, we see that the result does not change when we use only the significant variables. Figure 1 illustrates the results of the goal differences for each game in 2013-2014 season along with the fitted models using all predictors. In Figure 2, we kept only significant predictors in each fitted model.

Table 4 presents the percentage of predicting the correct winning team. That is the argument percentage of the signs of the empirical difference and the signs of the fitted models. From Table 4, we can say that the percentage of compatibility in predicting the exact signs of the differences in goals for Laplace, Skellam and trinomial difference is about the same and higher than the corresponding percentage for the extended binomial distribution. Table 5 presents the percentages of predicting the difference in goal with a margin error of one goal for the four models. Again, the Laplace, Skellam and trinomial difference models are almost compatible in predicting the difference in goals with a margin error of one goal.

3.2 ***Application 2 (Arsenal)***

The data is obtained from the English Premier League for 2013-2014 season. Data were downloaded from http://uk.soccerway.com/. We also considered fitting the goal difference for Arsenal, where the response variable is defined as Y= number of goals of Arsenal - number of goals of the other team in game i. The explanatory variables are the home effect (X_1), the goal difference in the previous year 2012-2013 for the same teams (X_2) and the points for the competing team in the game (X_3). Note that we eliminated the cases where there are different teams in 2012-2013 and 2013-2014. We fitted all models and then we eliminated the non-significant variables. Table 6 displays some descriptive statistics for response and explanatory variables. Table 7 displays the fitted models for all parameters. Table 8 displays the fitted models using only significant variables. Based on AIC, Table 7 indicates that the trinomial difference model provided a better fit than the other models. From Table 8, we see that the result does not change when we use the significant variables. Figure 3 displays the goal difference in each game between Arsinal and other teams in 2013-2014 season along with the fitted models using all predictors. In Figure 4, we kept only significant predictors in each fitted model.

As in the model for all teams, we calculated the percentage of predicting the correct winning team and the percentage of predicting the difference in goals with a margin error of one goal, which are exhibited in Tables 9 and 10. From these two tables, we concluded that the percentage of compatibility in predicting the correct winning team for Laplace, Skellam and trinomial difference is about the same and higher than the corresponding percentage for the extended binomial distribution. However, when we use the significant parameters, the percentage of predicting the exact difference in goals for Laplace and Skellam models is about the same and higher than the corresponding percentage for the other two models. Again, the Laplace, Skellam and trinomial difference models are almost compatible in predicting the difference in goals with a margin error of one goal, while when we use the significant parameters, Laplace model has higher corresponding percentage than the other models.

Table 2: Fitted models for goal difference (2012 -2013) in English Premier League.

parameters	Skellam		Laplace		trinomial difference		extended binomial	
	Estimates	p value	Estimates	p value	Estimates	p value	Estimates	p value
Intercept (β_{10})	-0.1248	0.7629	-0.3543	0.4663	-2.5427	<.0001	-0.1002	0.7087
Goal difference 2012 -2013 (β_{11})	0.0279	0.5678	0.0225	0.7107	0.0305	0.6699	0.6905	<.0001
Point home (β_{12})	0.0170	0.0005	0.0222	0.0005	0.0248	0.0032	-0.0958	<.0001
Point away (β_{13})	-0.0048	0.4079	-0.0013	0.0572	-0.0035	0.6656	0.0797	<.0001
Intercept (β_{20})	-0.4634	0.3475	-0.7680	0.1843	-2.9049	<.0001	0.6022	0.4630
Goal difference 2012 -2013 (β_{21})	-0.0055	0.9308	-0.0344	0.6406	-0.0041	0.9616	-1.0950	<.0001
Point home (β_{22})	-0.0014	0.8425	-0.0089	0.2561	0.0073	0.5024	0.1936	<.0001
Point away (β_{23})	0.0156	0.0096	0.0194	0.0052	0.0170	0.0346	-0.5019	<.0001
AIC	1100.3		1141.7		1099.0		10406	
BIC	1129.1		1170.6		1127.8		10435	
MSE	4.0264		3.2694		4.3194		10.5004	

Table 3: Fitted models using only significant variables in England Premier League.

parameters	Skellam		Laplace		trinomial difference		extended binomial	
	Estimates	p value	Estimates	p value	Estimates	p value	Estimates	p value
Intercept (β_{10})					-2.4929	<.0001		
Goal difference 2012 -2013 (β_{11})							0.6674	<.0001
Point home (β_{12})	0.0194	<.0001	0.0200	<0.0001	0.0209	<.0001	-0.0673	<.0001
Point away (β_{13})	-0.0088	0.0088	-0.0168	0.0005			0.0697	<.0001
Intercept (β_{20})					-2.7535	<.0001	0.5999	<.0001
Goal difference 2012 -2013 (β_{21})							-1.0551	<.0001
Point home (β_{22})			-0.0170	0.0018			0.1922	<.0001
Point away (β_{23})	0.0077	<.0001	0.0140	0.0025	0.0211	<.0001	-0.6437	<.0001
AIC	1093.7		1136.1		1092.8		13738	
BIC	1104.5		1150.5		1107.2		13763	
MSE	3.3052		3.2483		3.2491		12.9732	

Table 4: The percentage of predicting the correct winning team.

The model	Percentage (all parameters)	Percentage (significant)
Laplace	56.25%	58.09 %
Skellam	55.88%	56.25 %
Trinomial difference	57.35%	57.35%
Extended binomial	45.59 %	45.59%

Table 5: The percentage of predicting the difference in goals with a margin error of one goal.

The model	With a margin of difference goals equal 1(all parameters)	With a margin of difference goals equal 1 (significant)
Laplace	62.5%	62.13 %
Skellam	62.13%	61.76 %
Trinomial difference	60.29%	60.66%
Extended binomial	34.19%	29.41%

Table 6: Descriptive Statistics.

Variable	Sample size	Mean	Standard deviation	Minimum	Maximum	Skewness
Y	32	0.469	0.373	-6	3	-1.39
X_1	32	0.5	0.0898	0	1	0
X_2	32	0.719	0.299	-2	5	0.73
X_3	32	54.38	2.82	39	89	0.9

Table 7: Detail of the fitted model for data in English Premier League (Arsenal).

parameters	Skellam		Laplace		trinomial difference		extended binomial	
	Estimates	p value	Estimates	p value	Estimates	p value	Estimates	p value
(β_{10})	2.4953	0.0231	2.1937	0.1078	4.6265	0.0070	-4.0016	<.0001
(β_{11})	-0.3002	0.4954	0.0668	0.9095	-2.6260	0.0016	2.9994	<.0001
(β_{12})	0.1291	0.2570	0.1443	0.4190	0.1916	0.3289	0.3999	<.0001
(β_{13})	-0.0407	0.0772	-0.0432	0.1086	-0.0669	0.0249	0.0484	<.0001
(β_{20})	-0.8072	0.5118	-2.0693	0.2743	2.2600	0.1920	10.6015	<.0001
(β_{21})	-2.1540	0.0102	-1.7544	0.0592	-4.2543	0.0002	-7.0085	<.0001
(β_{22})	0.1874	0.4406	0.1794	0.5657	0.2040	0.5244	-0.0000	0.0089
(β_{23})	0.0248	0.1623	0.0384	0.1756	-0.0195	0.4612	-0.5632	<.0001
AIC	130.6		142.2		127.2		1465.3	
BIC	142.3		153.9		138.9		1477.1	
MSE	2.1237		2.3201		2.0567		10.9064	

Table 8: Fitted models using only significant variables (Arsenal).

parameters	Skellam		Laplace		trinomial difference		extended binomial	
	Estimates	p value	Estimates	p value	Estimates	p value	Estimates	p value
(β_{10})	2.8874	0.0040	2.9908	0.0165	3.2210	0.0026	-4.0016	<.0001
(β_{11})					-1.0621	0.0125	2.9994	<.0001
(β_{12})							0.3999	<.0001
(β_{13})	-0.0486	0.0248	-0.0554	0.0285	-0.0647	0.0031	0.0484	<.0001
(β_{20})							10.6015	<.0001
(β_{21})	-1.877	0.0146	-1.463	0.0645	-2.8855	0.0007	-7.0085	<.0001
(β_{22})	0.0123	0.0018					-0.0000	0.0089
(β_{23})							-0.5632	<.0001
AIC	124.5		136.3		122.6		1465.3	
BIC	130.4		140.7		128.5		1477.1	
MSE	2.3346		2.7563		2.1560		10.9064	

Table 9: The percentage of predicting the correct winning team.

The model	Percentage (all parameters)	Percentage (significant)
Laplace	71.88%	71.88 %
Skellam	71.88%	71.88 %
Trinomial difference	71.88%	59.38%
Extended binomial	59.38%	59.38%

Table 10: The percentage of predicting the difference in goals with a margin error of one goal.

The model	With a margin of difference goals equal 1 (all parameters)	With a margin of difference goals equal 1 (significant)
Laplace	78.13%	78.13 %
Skellam	78.13%	50 %
Trinomial difference	75%	53.13%
Extended binomial	37.5%	37.5%

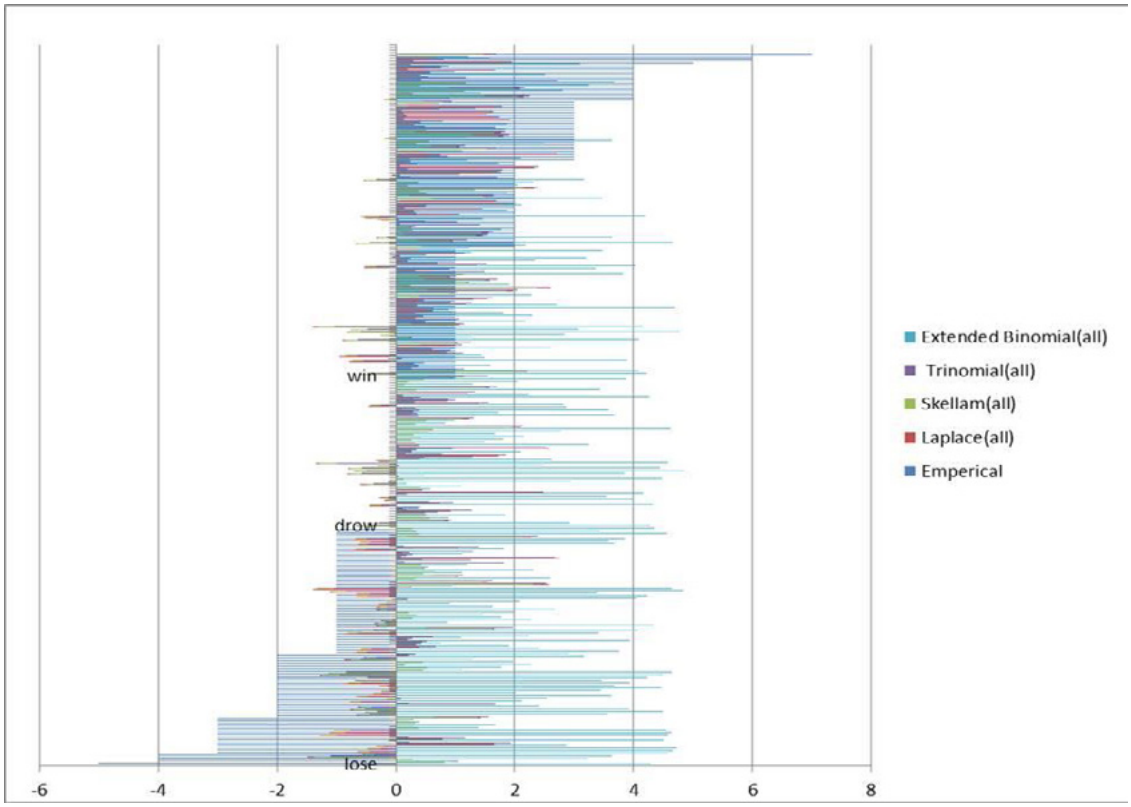

Fig. 1: Empirical versus the fitted values of the different models (all parameters).

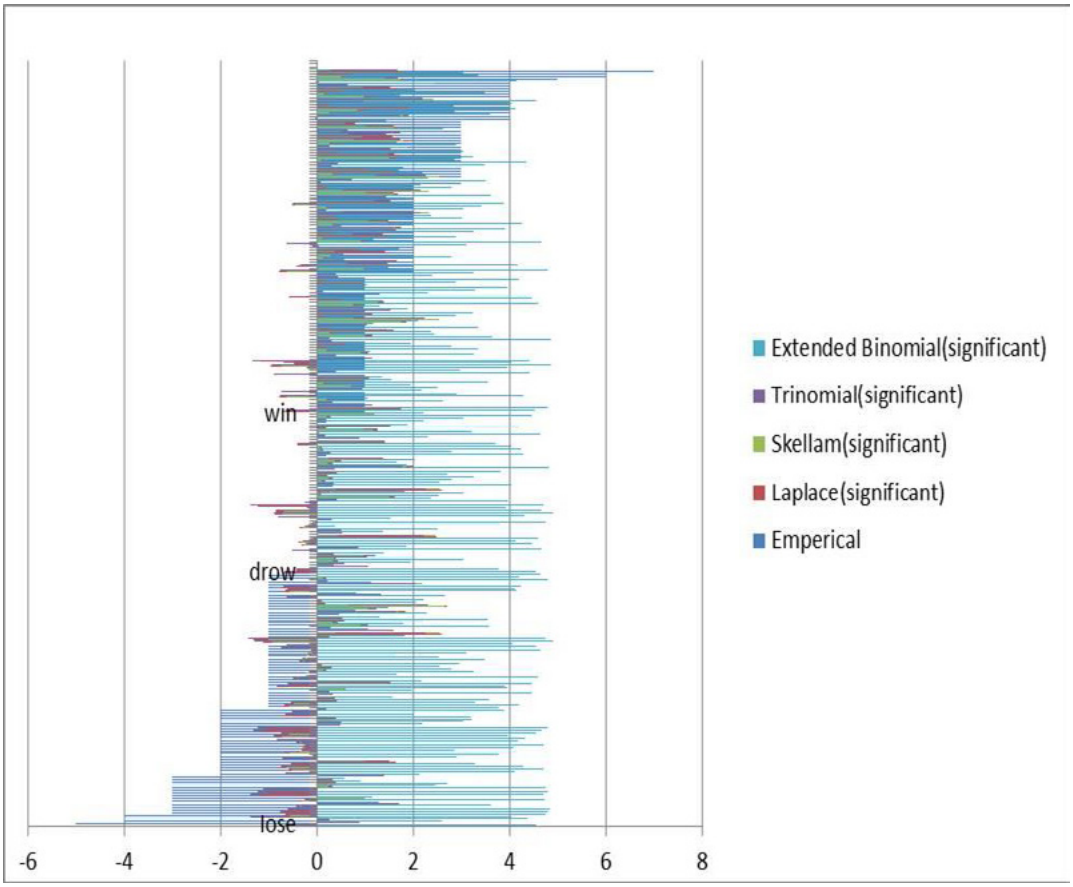

Fig. 2: Empirical versus the fitted values of the different models (significant).

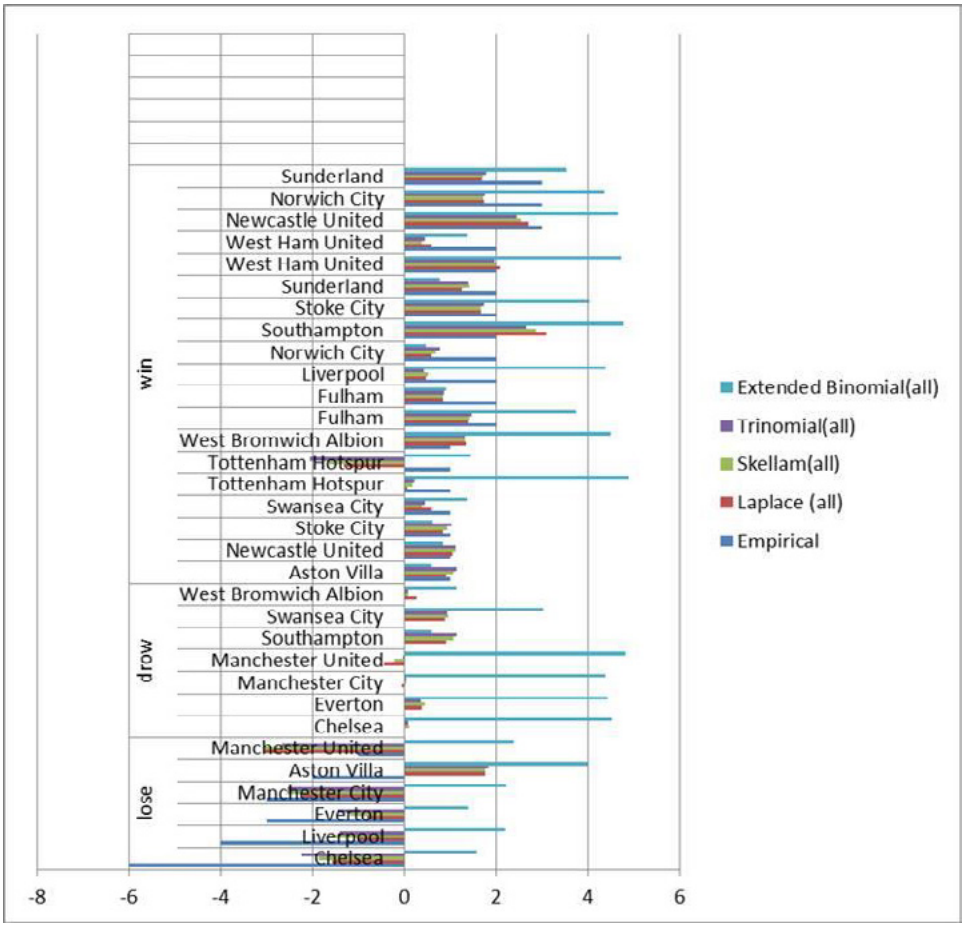

Fig 3: Empirical versus the fitted values of the different models (all parameters)

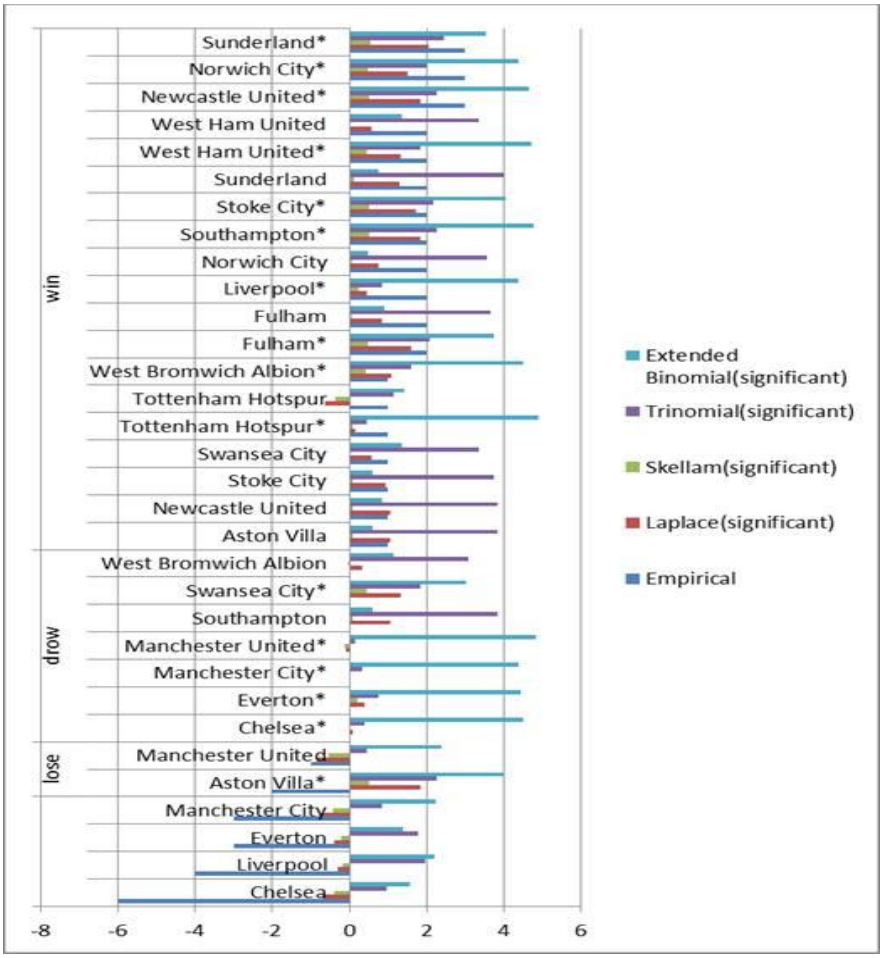

Fig 4: Empirical versus the fitted values of the different models (significant).

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Increase Accuracy of Toothed Vein by Gear-Shaving Operation

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ABSTRACT

Quality and technical features to product a machine building, in the composition which enter sprockets, to a great extent hang from the quality last. So for instance, inaccuracy of step of teeth cause additional dynamic loads in grappling, concentration of load appears at presence of inaccuracy of direction of teeth, inaccuracy of profile of teeth are reason for breaking a kinematics of mechanism. Reduction of inaccuracy of toothed vein allows greatly raise loading ability of issue, reduces size of mechanism, enlarges its CUA and lifetime. Experience of production and usage of toothed issues, study of intercoupling their technical level with methods of Form shaping toothed vein be indicative of that, technical level an index loading ability of toothed issue greatly depends on the method of clean processing teeth. From number of methods finishing processing teeth of sprockets in machine building broad using has a process gear shaving. In spite of greater amount of work, directs by theoretical and experimental study of process gear shaving, quality of processing sprockets does not exceed 8th degree accuracy. Considering that increasing of accuracy of processing sprockets can be an important reserve of increase the loading ability of issue and factors of technical level of product as a whole, way development of rising accuracy processing gear-shaving may be an actual problem for the theory tooth Form shaping and practice of machine building.

Keywords: Tooth vein; inaccuracy; accuracy; shaving; teeth; conjugate surface.

1. INTRODUCTION

Sprockets with number of teeth z = 6 ... 12 find a use in oil pumps, planetary transfers and many other mechanisms. Shaving these wheels inconveniently does not allow receiving accuracy of gear ring parameters above than 8 degrees on Standard (Russia) 1643-81. Considering that, increase accuracy of processing gear sprockets allows essentially to raise characteristics of products, development effective ways of their clean processing – that is very important scientific and practical task. Known Shaving methods disk cutter (Shaver) in conditions free rolling are known at rotation on crossed axes shaver and process able wheel, of longitudinal and radial submission Kohan(1962) . Lack of these methods is, that on surfaces teeth process able sprocket in zone dedendum circle cutting during processing, the layer of metal is more than size gap on processing, therefore on this site the profile of a tooth has the large error. Are

known a shaving methods disk shaver, at which for increase accuracy of an involute tooth profile sprocket in zone dedendum circle a tooth profile shaver modify (Sioia,1964; Luneev and Bulatov,1974) .

These methods have lacks. The first lack consists that size, form and situation of a site of the modified a tooth profile shaver depends on parameters of a process able wheel, owing, to what grows time for polishing cutter part of shaver. The second lack consists that size, form and situation of a site of the modified profile teeth shaver change on a measure cutter part shaver. As the size shaver change, owing, to what the processing cutter parts shaver becomes complicated. The third lack consists that the size, form and situation of a site of the modified profile teeth of the finally processed sprocket, owing to what the surfaces teeth of shaver and teeth of a process able sprocket on passes previous to last clean pass, are not connected. Because of it these ways do not allow to receive accuracy of processing above than eighth degree on standard 1643-81. The offered method shaving involute of gear cylindrical wheels allows increasing accuracy and productivity of processing (Naden ***et al***.,1997; Hamdan,1996).

2. MATHMATICAL ANALYSIS

The essence of an offered method consists that teeth on preparation before gear shaving cutting with an slopping angle distinguished from an slopping angle teeth of a finally processed sprocket on size

$$\Delta\beta_1 = \pm \frac{2\cos\beta_0 \cos\beta_1}{m_n\left(z_1 tg\,\beta_1 \cos\beta_0 + z_0\, tg\,\beta_0 \cos\beta_1\right)} \Delta a \qquad (1)$$

Where m_n - normal module, mm;

Z_1, Z_o - Number teeth of sprocket and shaver accordingly;

β_1, β_0 - slopping angles teeth of wheel and shaver on inside cylinders,

Appropriate to a situation to the termination process of processing Accordingly;

Δa - Gap on processing on center axial distance,

And at processing curve of sprocket teeth, an slopping angle teeth of preparation increase at the same direction teeth of shaver and sprocket; reduce at different aim a direction of teeth shaver and sprocket, and at processing straight teeth sprocket right shaver a direction of teeth of preparation is left, at processing left shaver it will be right.

At such performance of preparation on each pass, since first, provide conjugate the lateral surfaces teeth shaver and sprocket, that allow in tool machine gearing to execute the law of movement the spatial mechanism formed by shaver and sprocket

$$\frac{d_{\omega 0i}\cos\beta_{\omega 0i}}{d_{\omega o1}\cos\beta_{\omega 1i}} = \frac{z_0}{z_1} = const \qquad (2)$$

As, on each pass is satisfied condition

$$\Sigma = \beta_{\omega 0i} + \beta_{\omega 1i} \qquad (3)$$

Where $d_{\omega 0i}$, $d_{\omega 1i}$ - diameters of initial cylinders shaver and sprocket on given i pass accordingly;

$\beta_{\omega 0i}$, $\beta_{\omega 1i}$ -Slopping angle teeth shaver and sprocket on initial cylinders on i pass accordingly;

$\sum$ - Angle crossing of axes shaver and sprocket;

i - Number of pass.

On subsequent behind the first passes slopping angle teeth of a process able sprocket received after the previous pass automatically changes on size

$$\Delta\beta_{n-1} = \frac{2\cos\beta_0 \cos\beta_1}{m_n\left(z_1 tg\,\beta_1 \cos\beta_0 + z_0\, tg\,\beta_0 \cos\beta_1\right)} S_{ri} \qquad (4)$$

Where n - number of passages;

S_{ri} - Radial submission on i passage.

3. EXPERIMENTAL ANALYSIS

By the specified method processed straight teeth gear oil pump with number of teeth z_1 = 10, module m = 3 mm, factor of displacement x_1 = 0.3445, shaver without modify teeth profile, number teeth of shaver z_0 = 53, slopping angle teeth of shaver β_0 = 15°, direction of shaver teeth is right. Processing processed on universal toothed gear shaving machine tool.

Teeth of gears under gear shaving have cut on toothed milling machine tool and have a polish surface, leaving gap on gear shaving operation on inter axial distance Δa = 0.10 mm. Direction of sprocket teeth left with slopping angle $\beta_{\omega 1}$ = 0.4449°, which determined by equation 1.

4. RESULTS AND DISCUSSION

The results of measurement on each tooth of the maximal and minimal deviation parameters are given in table 1

Table 1. Maximal and Minimal deviation of accuracy parameters

Parameter	Designation	Deviation
Direction of teeth, micron	$F_{\beta r}$	1... 0
Palpation of a gear ring, micron	F_{ir}	8... 6
Fluctuation of length general normal, micron	F_{vWr}	6... 4
The defect of profile, mm	f_f	No more than 0.01 (did exceed thickness of drawing line tooth profile on all height of a tooth).

Analysis of results of experiments shoes that non dependence from source stocking up polish or non polish sprocket, already on first passages of inaccuracy of toothed vien is put in the rate 5^{th} … ^{6th} degree of accuracy at one draft pass.

5. CONCLUSION

1. Degree of reducing inaccuracy of toothed vein on the passage, which executed, depends on geometricies of surface of sprocket teeth, received on the preceding passage and corresponding to an angle slopping of teeth and crossbreeding the axis to the center axial distance on given passage.
2. The offered method allows already on first passages to get quality factors of toothed vein within 6^{th} degree of accuracy.
3. Realization the offered method shaving with variable angle slopping of sprocket teeth is not required modernization of tool grappling.
4. The offered method allows increasing accuracy and can be easy introduced in the production.

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